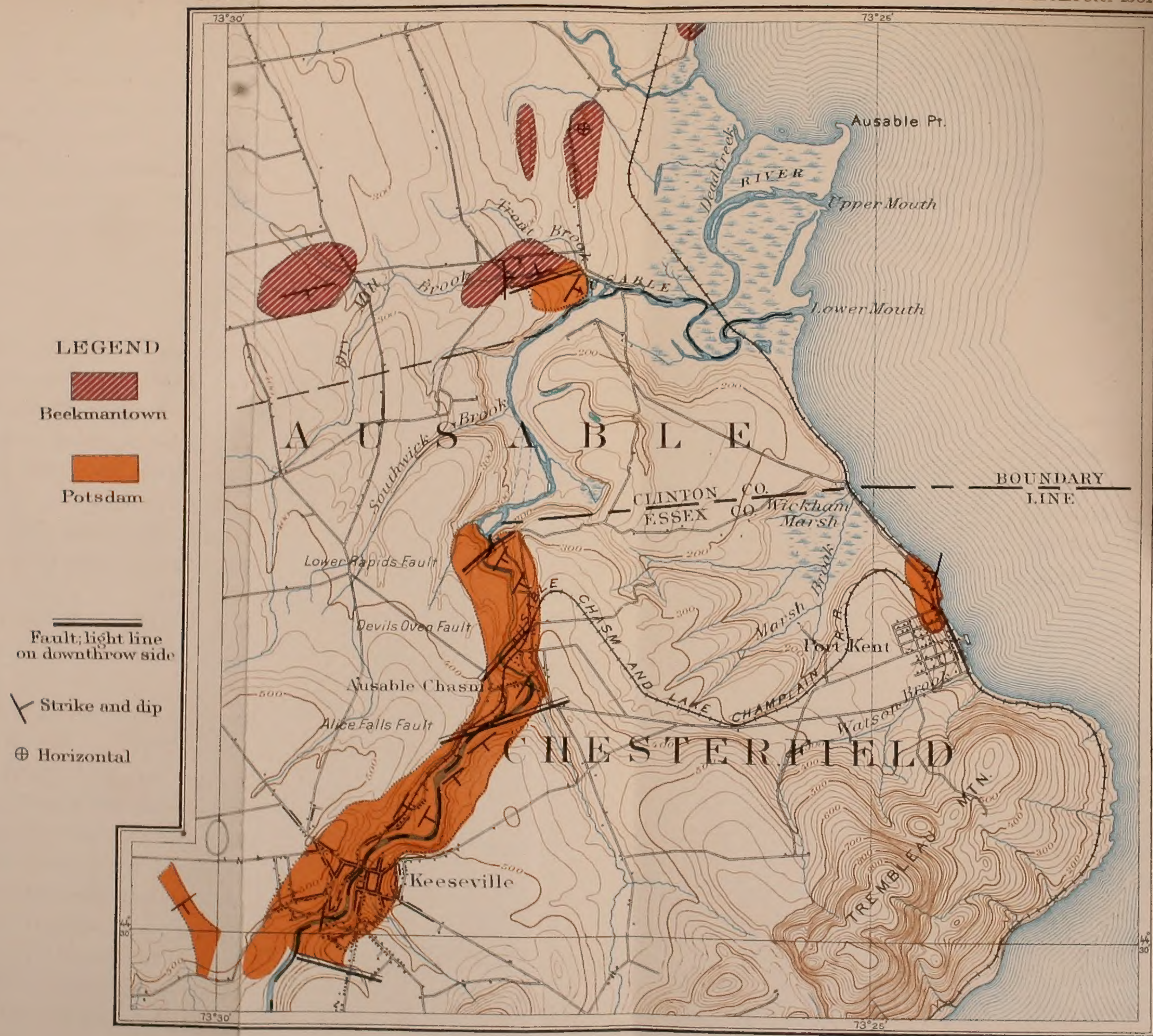

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PORTION OF S.E. CLINTON AND N.E. ESSEX COUNTIES
SHOWING EXPOSURES OF POTSDAM AND BEEKMANTOWN STRATA
G. VAN INGEN. 1901

Scale $\frac{1}{62500}$

Contour Interval 20 feet

Datum is mean Sea level

Stratigraphic map of Olean quadrangle

" Portage formation

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New York State Museum

FREDERICK J. H. MERRILL Director
JOHN M. CLARKE State Paleontologist

Bulletin 69

PALEONTOLOGY 9

REPORT OF THE STATE PALEONTOLOGIST 1902

ALBANY
UNIVERSITY OF THE STATE OF NEW YORK
1903

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University of the State of New York

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University of the State of New York

New York State Museum

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Bulletin 69
PALEONTOLOGY 9

REPORT OF THE STATE PALEONTOLOGIST 1902

To the Regents of the University of the State of New York

I have the honor to report herewith on the work of this department during the year commencing Oct. 1, 1901.

Operations in the field 1901-2

Guelph horizon and fauna. In my report of last year I had occasion to make reference to investigations relating to the distribution of the Guelph horizon and its fauna throughout western New York. This interesting congeries of fossils, constituting essentially a new element in the Paleozoic faunas of the New York series of geologic formations, had at that time been found only in the vicinity of Rochester, with the exception of an early locality in Wayne county mentioned by Professor Hall in 1843, but subsequently lost. As noted in the report referred to, our effort of that year to locate other manifestations of this horizon between Rochester and Niagara Falls along the summit of the Niagara escarpment was not successful in its main object, though contributing interesting data bearing on the contact outcrops of various formations immediately involved. The horizon of the Guelph lies so involved with the upper beds of the dolomite series which constituted the closing episode of the Niagaran stage in New York, and these dolomites are, notwithstanding their massive and resistant character, so seldom exposed in continuous section, that the few natural cliff exposures through this region are very unsatisfactory for the determination of the contents of the strata.

Early in the present season, however, an artificial exposure along the banks of Oak Orchard creek directly south of Shelby, Orleans co., was reexamined and found to contain evidence of the Guelph fauna for which we had been diligently searching. Here a channel has been cut through the natural rock bed of the creek in the construction of a feeder for the Erie canal and drainage way from the Oak Orchard swamp lying to the south, and, taking the exposure at low water and before the vegetation had become profuse, it was practicable to make out the succession of the dolomite series with clearness and also to locate therein two horizons of the Guelph fauna, the lower of which has proved remarkably prolific in organic remains and these of extraordinarily interesting character, supplementing very materially the knowledge we had already derived of this fauna from its development in and about the city of Rochester. It would appear from a closer analysis of these aggregations that the upper Guelph horizon, which lies 30 feet above the lower, is to be correlated with and doubtless is coextensive with that at Rochester. Following this discovery, the attempt was renewed to locate the horizon at other localities, specially in the continuous section at Niagara Falls, and, though here the section is essentially a vertical one and the rocks difficult of access, the effort to locate these horizons in that section proved successful. Similarly, at various localities from Niagara Falls to Shelby near and south of Lockport, Gasport and Middleport, the horizons were followed, and also west of Shelby in the towns of Barre, Clarendon and Byron, at Clarendon there being an exposure of considerable continuity. At none of the localities, however, except at Shelby were the horizons found to be fossiliferous except in the presence of an occasional species of this characteristic fauna. The problems presented by this fauna, both biologic and stratigraphic, have been carefully studied and are embodied in Memoir 5 of the State Museum, which is now essentially printed, and to which reference is made under another head.

The fauna of the Naples beds. In order to help to a conclusion a monograph now long standing, on the Naples fauna of the Portage stage in western New York, one part of which has already been published, Mr D. D. Luther carried on investiga-

tions in Erie and Chautauqua counties. This study has involved some questions in regard to the determination of the upper boundary of the Portage formation which can be fixed only on the basis of the evidence to be derived from the fossils. The organisms themselves are also for the most part undescribed and constitute one of the remarkable associations of fossils in our older rocks. The fauna of the western New York Portage or the Naples fauna has been shown to have entered the State from the west and not to have penetrated far beyond the meridian of Cayuga lake. Its path of migration into the western boundaries of the State is evidently buried at the bottom of Lake Erie; but, to determine whether any trace of the fauna is to be found to the south or north of the lake, some investigations were carried on in Erie county, Pa. to ascertain the significance of the formations termed by the Pennsylvania geologists "Portage" and "Girard shales." The Portage, it has now been made evident, does not there exist, and the faunistic value of the Girard shales is a matter for further study. In Ontario the black shale beds at Kettle Point, Lake Huron and about Sarnia, Forest and Alvinston, which have been recorded as of Portage age, show no definite relations to the true Naples fauna, but rather represent only the condition which prevailed during the deposition of all the black muds of the Genesee and lower Portage stages. All these field operations undertaken during the early part of the season were greatly embarrassed by the tremendous and protracted rainfall, which flooded the watercourses of the country to such a degree that they became virtually inaccessible, and for some weeks it was necessary to discontinue field work altogether.

The study of the Naples fauna is now brought to virtual conclusion, and the manuscript for some portion of it is in the printer's hands for a memoir of the State Museum. Brief reference will be made to this also under the caption of office work.

The "Hudson river" formation and faunas of eastern New York. In continuance of his previous investigations of the "Hudson River" formation, accounts of which have appeared in various museum bulletins and reports of the paleontologist, Dr R. Ruedemann was engaged in Rensselaer and Washington counties. The construction of a tunnel for the extension of the water

supply of the city of Troy is affording a section rather more than 1 mile in length through the shale region north of the Tomhannock river and, by the courtesy of Prof. W. G. Raymond, engineer in charge of these operations, we have been permitted to examine the section in all its parts in great detail as the rock is taken out. This section has already furnished some fossils which indicate the geologic age of the shales through which it runs; but, for the most part, the rock section has proved there, as usual in most exposures of the eastern Hudson river shales, comparatively devoid of these conclusive evidences as to its geologic age.

The discovery of a profuse graptolite fauna at the Deep kill, Rensselaer co. as noted in my last report, wherein are represented the three zones of the Phyllograptus shales of Europe or the lowest part of the Lower Siluric, has suggested the possibility of producing a map of that region on which may be distinguished all the graptolite bands of the Lower Siluric shale facies. During the present season investigation toward this end has covered the southeastern part of the Cohoes topographic sheet, with the Hudson and Hoosic rivers as western and northern boundaries respectively.

A discovery of considerable importance for the correlation of the shales throughout this region was made incidentally in the finding, in the vicinity of Schaghticoke, of the horizon of the fossil Dictyonema flabelliforme with associated species, all of which are regarded as indicating throughout northern Europe, and wherever found, the top of the Cambric series. This horizon has not before been found within the United States. This is a distinct contribution to the faunas heretofore represented in the New York series.

The areal map of the Tully quadrangle. The work on this quadrangle was virtually done during the previous season; but it seemed, on careful revision of the map prepared, that the stratigraphic divisions were insufficiently detailed, and, to carry out a more minute subdivision of the strata based more specially on paleontologic evidence, the work has been reviewed and is now brought to a satisfactory completion.

Work on the Elmira quadrangle; cooperation with the United States Geological Survey. Under the same conditions as have

heretofore prevailed in developing the stratigraphic and paleontologic relations on the Olean and Salamanca quadrangles, we have this year carried forward to completion, in cooperation with the United States Geological Survey, similar work on the Elmira quadrangle. On this work Messrs Myron L. Fuller and F. G. Clapp were detailed by the director of the United States Geological Survey, and this department was represented by C. A. Hartnagel and H. S. Mattimore in the necessary collection of fossils. The area covered by the Elmira quadrangle being in some degree lower down in the rock series than the areas of the Olean and Salamanca quadrangles, the questions which there arose in regard to the classification of the culminating geologic horizons have not been revived in this case. Most of the territory about Elmira is underlain by rocks of the Chemung stage, though at the north, in the low lands and valleys, are small, restricted areas of the Portage formation directly underlying. Sections however do not rise to any considerable hight, so that the hill summits do not enter on the horizons of the Wolf creek, Salamanca or Panama conglomerates. On account of the simplicity of the stratigraphic problem here involved, the time required for the field work was not long. The area between the Elmira and the Olean quadrangles is as yet but partially surveyed, and no maps have been made available for stratigraphic work, but it is on these intervening quadrangles that we may expect to find additional and important light on the problems which have arisen in the detailed study of the geologic succession in Cattaraugus and western Allegany counties.

The fauna and stratigraphic relations of the Coralline or Cobleskill limestone. "Coralline limestone" is a term applied by Prof. James Hall to a fossiliferous formation in eastern New York which he believed to be the eastern extension of the Niagara or Lockport dolomites of the Upper Siluric. The name was not one of the original elements in the nomenclature of the formations as proposed by the four geologists, though the term was originated by and had been in local use by John Gebhard, the pioneer of geology in the region about Schoharie county where this formation is best developed, and was also employed by

Mather in describing the rock series exposed at Rondout, Ulster co. This formation, which is in typical section in Schoharie county, as at Howes Cave and along the Cobleskill, is a dark limestone abounding in corals and carrying a considerable fauna besides, which has been described by Hall in volume 2 of the *Paleontology of New York.* It is underlain in this section by a mass of 30 to 50 feet of soft gray shales and, further east along the Schoharie creek, this mass is lessened and the shale is of greenish color. Professor Hall regarded this underlying shale as pertaining to the Clinton formation, and, on account of the stratigraphic position of the Coralline limestone and because of the nature of its fossils, many of which he found to be identical with or similar to known Niagara species, he concluded, as above stated, that it was an eastern representative of the Niagaran formation not otherwise known in this part of New York State. The value of this determination has been brought into question by several writers, specially as a more careful study of the fauna of these beds indicates, notwithstanding its affiliations to the Niagara fauna, specific identities of notable importance with species which occur in higher horizons in the State of New York. Thus we have observed that, above the waterlime formations at the top of the Salina stage in western New York, probably 1000 feet higher than the last appearance of the Niagaran fauna, species occur which are identical with the Coralline limestone species of eastern New York, and these points of similarity have been quite clearly pointed out in a recent publication by Prof. A. W. Grabau. We have had previous occasion also to direct attention briefly to the occurrence of a profuse development of a fauna similar in many particulars, in a quite pure limestone interbedded between the upper and lower waterlimes of the Salina formation at Frontenac island, Cayuga lake. Now, though the Coralline limestone with its characteristic fossils appears in Schoharie and Otsego county sections to lie below the waterlime formation as a whole, in the sections exposed at Kingston and Rondout and early described by Lieutenant Mather in his report on the geology of the first district, the formation and its fauna apparently make a double appearance, lying at first below the

cement rock, as at Rondout, and then reappearing after the deposition of a considerable thickness of waterlimes, and the second appearance followed again by more of the cement rock. The lowermost of these beds is not the equivalent of the typical or Schoharie county Cobleskill but its fauna carries a much stronger impress of Niagaran age. We are compelled, for purposes of correlation east and west, to designate this bed by a distinctive term and shall call it the *Wilbur limestone.*

The Cobleskill beds on Cayuga lake at Frontenac island are involved in somewhat similar stratigraphic condition to the upper bed or true "Coralline" at Rondout. We had undertaken a few years ago to work out the various bearings of the data set forth by this interesting fauna and formation, specially its manifestations in central and western New York. During the past season field studies have been carried forward in the eastern part of the State. It is too soon to state definitely the outcome of these investigations; but this much is clear at the present time, that the fauna of the Coralline limestone, in its first appearance in the Rondout section, contains an important percentage of species which have very close relations even to identity with species of the Niagara dolomite. This resemblance is essentially lost in the higher horizon at Rondout which is equivalent to and probably continuous with the typical Coralline outcrops in Schoharie county. Several of these very characteristic forms occur in the Guelph fauna, which we have elsewhere described, and others, as just noted, reappear in a still later manifestation, in fact the final stage of the Siluric faunas in western New York. In the proper interpretation of the stratigraphic relations of these faunas much will depend on the valuation of the beds which underlie the limestone in the Schoharie county sections, and which were called and have heretofore been commonly granted to be of Clinton age.

Messrs Ulrich and Schuchert put forward, in the last annual report of the paleontologist, in an important paper entitled *Paleozoic Seas and Barriers in Eastern North America,* the hypothesis that, during this late Siluric period, a land barrier crossed New York State from northeast to southwest, and that the Coralline fauna was a provincial development pertaining to the region outside or eastward of the barrier, while other phases

of late Siluric faunas were holding the ground on the inner or mediterranean side. The arguments in support of such a barrier in eastern New York during various epochs of Paleozoic time are strong and have been well constructed by the authors referred to. Their hypothesis proves of great service in properly construing the long known and palpable difference in the development of the Paleozoic rocks in eastern New York and in the central and western parts of the State. We are disposed to believe that the complete analyses of the proposition now before us concerning the value of the Coralline limestone and fauna will throw important light on the existence and influence of such possible land barrier during late Siluric time.

We have above and previously used the expression, "Cobleskill limestone," as an alternative name for this formation, in view of the fact that stratigraphic names seem to meet modern requirements only if designated by geographic terms. The term "Coralline" is unfortunate in many respects; it originally had reference to the abundance of corals in the rock, but the word is now used with a different signification, and, while it has no geographic value, it has neither the biologic importance which such term should carry. The Cobleskill presents the best sections of the formation to be found in the region of its typical exposures.

Mr C. A. Hartnagel, who has been specially concerned with the study of this problem, communicates the following account of his field operations:

Work on the Cobleskill formation. This report is a brief account of the field work during the greater parts of the months of August and September, on the Cobleskill formation. For convenience the region studied is here considered in three sections. *First*, that extending from Gallupville, Schoharie co., west and northwest through Shutter's Corners, Schoharie, Howes Cave, Central Bridge, Grovenor's Corners, Carlisle, Sharon Springs and the section to the north and northwest of Cherry Valley in Otsego and Herkimer counties. *Second,* that section in Albany county, along the northern and eastern ends of the Helderberg plateau, extending from Altamont, and including the Indian Ladder and New Salem sections, to South Bethlehem. *Third,* the section extending from Catskill in Greene county, south

through West Camp, Saugerties, Glasco, Lake Katrine, East Kingston and Kingston (Rondout). From Kingston this section extends southwest through Wilbur, Eddyville, Whiteport, Binnewater, Rosendale to High Falls, all in Ulster county.

1 *Gallupville.* On the left of the road leading north past the cemetery, from Gallupville, at a distance of ½ mile from the village, there is exposed, though somewhat obscurely, the Cobleskill formation together with the underlying Salina shales. The Lorraine shales are well shown here, as is the Rondout series above the Cobleskill. This is the only section where the Cobleskill has been observed north of the Fox kill. Professor Prosser, at a point farther west, near Shutter's Corners, has observed the Rondout, but a careful study of the vicinity did not reveal any outcrop of the Cobleskill.

Shutter's Corners. One half mile south of Shutter's Corners on the farm of Seth Stevens, occurs an outcrop of the Cobleskill. The weathered condition of the rock at this station has made it favorable for collecting, though here and continuing for more than a mile westward the vicinity of the outcrop is of a swampy nature, owing to the low dip and the wearing away of the softer rock above. Between this station and Schoharie the formation is exposed at several points, and, where not exposed, its position is marked by a small ridge rising above the general level of the land.

Schoharie; east side. To the east and northeast of Schoharie, running obliquely up the hill from the African church, is an almost continued exposure of this formation. This outcrop has been noted by Mr Darton, and it is said that most of the Coralline fossils of the William Gebhard collection were obtained from it. One fourth mile east of the postoffice at Schoharie, the shales underlying the Cobleskill are exposed by the roadside, and a few rods farther brings one to the old Brown quarry, at the base of which is exposed the Cobleskill, followed by what is evidently a cement rock nearly 5 feet thick. Above is a limestone in two layers of nearly equal thickness, their total thickness being 50 inches. They here form the roadbed and can be traced a hundred yards farther south to where Mr E. Vroman has recently opened a quarry in them. These layers are worked as " Coralline." In- **Vroman's quarry**

tercalated between them is a somewhat shaly layer with abundant corals.

Schoharie creek sections. On the west side of Schoharie creek, besides the well known exposure south of the creek bridge, the Cobleskill is exposed at Clark's cave, ¼ mile north of the bridge. At this point the Lorraine shales are well shown, and the contact with the Salina shales can be seen. There is another exposure of the Cobleskill on the east side of West mountain, at the strontianite mine 1 mile north of Clark's cave. Farther along on the northeast point of the mountain the rock is shaly, and collecting is good. Still farther along, nearly opposite Central Bridge, there is a similar exposure with fossils. From this point to Howes Cave there are no good exposures on the mountain side, and the dip soon brings it below the surface when a lower level is reached.

Howes Cave. The Howes Cave section is well known, and from this point the formation is somewhat obscured for some distance to the north, but, at a point 1 mile below and ½ mile from the highway leading to Central Bridge, there is exposed in the creek bed the Cobleskill together with the Salina shales and the Lorraine beneath. This section is one of the best at which to observe the contact between the different formations. Beyond this station and nearly west of Central Bridge, on the farm of Mr Tarr, there occur very large boulders of Cobleskill arranged in nearly a straight line, from which corals may be had in large numbers. A mile and a half farther north from this point the limestone outcrops by the roadside at the house of Eugene Maxwell. The overlying rock has been removed by erosion, and considerable of the upper surface of the Cobleskill is exposed at this point, and on the road to Grovenor's Corners, where frequent exposures are seen, specially near the house on the Judson Grovenor farm and at several points on the farm of Sol Dewey.

Grovenor's Corners. At Grovenor's Corners there is a fine exposure, and this outcrop continues at intervals for nearly a mile on the road to Carlisle.

Carlisle. One mile northwest of Carlisle is the last good exposure of the Cobleskill on the way to Sharon Springs, but there are several points where its presence can be detected and

fossils obtained. But within 3 miles of Sharon Springs no exposures have been noted.

Sharon Springs and Cherry Valley. At Sharon Springs and the section north of Cherry Valley it is clearly evident that there is no limestone between the Lorraine shales and the so called Salina shales above. Westward from Cherry Valley and extending into Herkimer county the Salina shales rest directly on the Clinton formation showing that there can be no Niagara present in this section.

2 *Altamont.* In the Helderberg at Altamont, there is a space occupied by an impure limestone which may be referred to the Rondout. This limestone rests on the Lorraine shales. The same condition exists at the Indian Ladder. At South Bethlehem the Rondout is somewhat thicker and it is said would make cement. The contact with the Lorraine shales was seen at this point.

A short distance south of New Salem there is a thin layer of sandstone lying on the Lorraine shales and below the Rondout. The sandstone contains iron pyrites, and Professor Prosser has provisionally referred it to the Clinton. It may now properly be included in the Rondout.

Catskill. In the region southwest from Catskill are found the remains of corals and some brachiopods below the Rondout beds, and often the corals are directly on the Lorraine shales, which at this point appear to be conformable with the overlying rocks. South, near West Camp, at the end of a syncline extending from the Catskill region, there is exposed in both limbs of the syncline, about 3 feet of the Wilbur limestone. At this station a number of Leptaena rhomboidalis were found. From West Camp south through Saugerties one can only hope to find the Cobleskill in the limbs of the anticline, which passes from some distance west of West Camp through Saugerties and finally into the Kingston region. The western limb of this syncline was not examined, but the eastern limb in the section about Saugerties is eroded, and only the higher formations can be seen. At Glasco there is a somewhat obscure outcrop, but farther south, beyond Lake Katrine and near East Kingston, there is a fine exposure. About 2 feet from the bottom there is a thin layer crowded with Atrypa reticularis. From this point the limb of the anticline is either obscured by the Champlain clays of the Hudson valley or eroded. At the Newark Lime and Cement Works the Wilbur is shown at several points. Several less important outcrops occur at Wilbur and Eddyville. Outcrops are also found across the Rondout creek opposite Wilbur. These relations hold good

almost to Rosendale from Rondout along Rondout creek, but from Kingston through the Whiteport-Binnewater stations the cement lies on a floor of sandstone (Clinton).

The cement at Rosendale is also on a base of sandstone, but at this point I have found small Leperditias in large numbers. They seem however to belong to the cement above.

At High Falls there is a thin shaly layer above the sandstone and distinct from the cement beds above. This shaly layer contains an interesting fauna and seems to be equivalent to the Wilbur.

It is to be noted that, throughout the cement region in Greene and Ulster counties, the cement beds above the Wilbur occur in two layers, between which is found the Cobleskill containing an abundance of corals, mostly Halysites. This limestone in the Whiteport-Rosendale region is about 12 feet thick as a rule. However, in the Newark works at Rondout this layer is only 7 inches thick. The faunal contents of this limestone in Ulster county have not been examined in detail but suggest some very interesting studies.

The stratigraphy of Becraft mountain. Just east of the city of Hudson in Columbia county, is Becraft mountain, which has long been known as one of the interesting features in the Paleozoic geology of this State. The mountain is the only outlier east of the Hudson river of the Helderberg series of formations, on which lie in proper succession other members of the Devonic series to and into the Onondaga limestone. It has been the subject of much study. Accounts and sections were given of it by Lieutenant Mather in his report on the first district of New York, and he then indicated the essential tectonic structure, which is that of a low syncline of the higher deposits resting unconformably on the upturned edges of the Hudson river slates. At a later date the structure of the mountain was more fully elaborated by Prof. W. M. Davis; and subsequently the writer specially studied an outcrop of the Oriskany sandstone thereon of new interest in the composition of its fauna, and published a somewhat extended account of this element in the make-up of the hill [Museum memoir 3]. In all these various studies, however, it has been clear to the observers that we had not yet reached a true solution of the structure of the mountain as a whole. Evidence of faulting and displacement at the southeast end was recorded by Mather and reiterated by Davis, but it has not been clear how profound were these

disturbances or how deeply they may have effected the rest of the mountain mass. For the most part, the mountain stands with abrupt sides in all directions except toward the southeast, being a wall of Manlius limestone underlain by the Hudson river shales. Such disturbances as it has undergone would be determinable with difficulty except by the aid of paleontologic facts. The interest pertaining to this area, the extensive series of exposures running through a number of highly fossiliferous deposits, the instructive illustrations which it affords of denudation, folding, overthrust and displacements of various kinds and the easy accessibility of the locality have justified a more careful study of the area than has heretofore been made.

This work has been specially facilitated by the fact that we have been able to plot the results on a topographic map of the area, prepared at the expense and under the personal direction of Dr John C. Smock, formerly assistant in charge of the State Museum, later, state geologist of New Jersey and now a resident at Hudson. The areal work on this problem has been assigned to Prof. A. W. Grabau of Columbia University, who has this season spent some weeks on the ground and has arrived at a satisfactory analysis of the structure involved. According to his determinations, this proves to be much more complicated than had been supposed, and the succession of rocks and faunas there exhibited will, when properly displayed on the map, throw new light on the forces which were efficient in upturning the fossiliferous sediments of eastern New York. Dr Grabau's work is essentially finished, and his results thereon will be found in another part of this report.

The Westfield mastodon. In the month of June I was informed of the discovery of mastodon remains in the village of Westfield, Chautauqua co. Such discoveries, though of frequent occurrence, are worthy in every case of investigation and record, and in this instance the situation was as follows. The bones were accidentally discovered while an excavation was being made on the property of Mrs Alice Peacock. The lot in which they were found to occur lies along the Nickel Plate Railroad, and is bounded on one side by the barn pertaining to the property and on the other by the highway. Across the highway is a low swampy area which extends for some distance to and

beyond the railroad right of way. In digging over Mrs Peacock's lot for the purpose of constructing a fish pond, bones were found lying on a pavement of heavy stones and just below a thin layer of muck. At the time of my visit on July 4 there had been taken from this excavation, one tusk, a number of ribs and vertebrae, part of the scapula, pelvis and sacrum. The ground had then been well dug over, and the prospect of finding other bones did not seem altogether favorable, nor had enough been secured to make the acquisition of them particularly desirable. It is quite probable however that more of the bones of this skeleton might be found by judicious excavation of the low land on the opposite side of the highway.

Our attention is so often directed to the finding of mastodon bones in this State that I have undertaken to bring together in another part of this report, simply as a matter of record, a list of such discoveries made, so far as records show, within the boundaries of the State. This list may be imperfect, but it is a significant one. There appear on it entries of about 60 different finds of this kind; and, while the most complete of the skeletons have been found in the swamps of Orange county, the record shows that the remains have been also pretty freely distributed throughout the western part of the State. I have pointed out there that these occurrences for the most part indicate that mastodons roamed the territory of New York probably in such abundance as the buffalo roamed the western plains 40 years ago. It is not a matter of wonder that few complete skeletons are found, as these remains are located mostly close to the surface, and such parts as were left exposed to the action of the air have naturally crumbled, while still other parts may have been destroyed by rodents or through other organic agencies. And it is also noted that the location of these bodies, not far from the surface and, in the vast majority of cases, on swamps deposited on relatively recent river terraces or lake beaches, goes to indicate that the interval of time separating the present from the day of the mastodon is not great; that these animals pertain to a late stage in postglacial history and were doubtless contemporaneous with man, as is specially indicated by the Attica mastodon excavated by the writer in 1887.

Other field work. Mr Richard F. Morgan has made for us some collections in the Marcellus limestone, temporarily exposed at Stony point south of Buffalo, at a time when such collections were much needed. Mr H. S. Mattimore has also collected to some extent in the Black river limestone in Jefferson county.

Office work

Memoir on the Guelph fauna in the State of New York. Reference is made on a previous page to the field work done during the past season with reference to these investigations. We have brought together in the memoir now in press a detailed account of this fauna, which, in New York, has risen to the very considerable representation of 70 species. It has been shown that this characteristic Guelph fauna, constituting virtually a new element in the Paleozoic limits of the State, entered from the west, penetrating as far east during the period of the deposition of the Niagaran dolomites as eastern Orleans county, and then retreated, reappearing after an interval in which some 30 to 40 feet of Niagaran dolomites had been deposited, and in the second invasion reaching as far east as the vicinity of Rochester. This second appearance of the fauna was less complete in species than the first, and its horizon lies at or very close to the summit of the dolomites, making thus a phenomenon pertaining to the closing stage of the dolomite episode. The little cluster of fossils of this fauna, which were reported as long ago as 1843 by Professor Hall from the Erie canal at Newark, Wayne co., a locality from which nothing more has ever been obtained, seems to have come from a still higher horizon within the basal deposits of the Salina shales, where, under unfavorable conditions, the impoverished representation of the Guelph fauna made its final appearance. The consideration of this fauna, which is illustrated by 21 quarto plates, involves the analysis and discussion of the nature of the sea and of the sediments of the Guelph period of time; and we have shown with reasonable conclusiveness that these deposits are ascribable to coral reef formations occurring in an inclosed and shallowing sea, which was gradually approaching the conditions essential for the free precipitation of salt and gypsum, such as prevailed during the succeeding Salina stage. The sea was one

comparable in many respects to the present condition of the Red sea, receiving comparatively little fresh-water drainage with its exit to the ocean body constricted, and its shore lines dotted with coral reefs, on which flourished in immense profusion a great variety of forms of invertebrate organic life.

Memoir on the fauna of the Naples beds. In the 16th annual report of the state geologist, I published an account of the Cephalopoda of the Naples fauna, in which the great abundance of heretofore undescribed species was made known. Next in interest to the cephalopod element of this fauna come the lamellibranchs, and of these nearly 70 species are now described in the memoir in hand, together with such species of gastropod and other mollusca as appear in the fauna.

This remarkable contribution of new facts is by no means the sole justification for the presentation of the Naples fauna. It is well recognized that this organic congeries, known as the fauna of Manticoceras intumescens, is one of the most persistent and widespread of the zones of organic life known in geologic history. Its affiliations with other manifestations of this zone have been pointed out in a general way by the writer on other occasions, but this presentation affords the first opportunity for a close analysis of the elements of the fauna and their comparison with their manifestations in other countries. These investigations have led further to a clear conception of the conditions under which the fauna flourished and of its relations to contemporaneous faunas within the State of New York, so that we are now able to derive a definite idea of the diversity of the geographic provinces which existed during Portage time. Of these we have frequently spoken, recognizing the fact that the Naples fauna or the western fauna of the Portage time was an invader from the west, but till now we have not seen clearly that this western or Naples fauna is itself divided into two geographic elements, one of which penetrated farther east than the other. So that in Portage time we find that the eastern part of the State was occupied by a brackish or estuarine fauna represented by the Oneonta beds, the central region by the autochthonic Ithaca fauna derived from its immediate predecessor on the ground, the Hamilton fauna, while the western province, which we have termed the

Genesee, occupied as a whole by the Naples fauna, was divisible into two subprovinces, the eastern or *Naples* and the western or *Chautauqua.*

This memoir, it is hoped, will be printed during the current year and will be accompanied by about 20 quarto plates of illustration.

Catalogue of type specimens of Paleozoic fossils. A year ago I announced that the compilation of this catalogue had been completed and the printing begun. Printing has continued without interruption during the past year, and at the date of writing there are 650 pages completed. The work goes slowly, as it is one requiring great accuracy of treatment, but I hope to report the catalogue published before another year. With complete entries of all the type specimens now in our possession, the number of which constantly grows, the book will not fall far below 1000 pages and will include considerably over 5000 entries. Concurrent with the work of printing this catalogue, the labeling and ticketing of the types has been carried forward to correspond with the numbering in the catalogue itself. This has involved bringing most of our type specimens together in our rooms in the State Hall, though some part of them are left in their places in the exhibition collection in Geological Hall, because of the difficulty of replacing them with other specimens without disturbing the arrangement there. The work of arranging the types has been largely in the hands of Mr Mattimore and has been carried out with much care.

The crustaceans from the Salina (Pittsford) shales in Monroe county. In my first report I noted the fact that the museum had by purchase come into the possession of a unique collection of heretofore unknown fossils from a horizon at the base of the Salina shales, also unknown till that time. This is a thin layer of black shales made known by excavations in the Erie canal near Pittsford in the year 1897. So distinctive is the character of this formation and its fauna that we are distinguishing the layer by the term *Pittsford shale.* Mr C. J. Sarle, of Rochester, was the discoverer of the horizon and the fossils. When Mr Sarle's collection passed into the hands of the State, he was promised an opportunity to publish with us an account of the peculiar eurypterid

Crustacea contained in this fauna, and this very interesting publication is presented with this report.

Mr Sarle has spent some weeks here, engaged under my direction in prosecuting his studies, and the objects which he first brings to public notice will be esteemed of much interest to all students of these ancient and primitive crustaceans, specially the proposed new genus Hughmilleria, which is intermediate between the well known genera Eurypterus and Pterygotus. Two years ago the writer described some of the phyllocarid Crustacea from these Salina shales and one form of the strange genus Pseudoniscus, so that now the entire list of crustaceans from the shales is as follows:

Emmelezoe decora *Clarke*
Ceratiocaris (Limnocaris) praecedens *Clarke*
Pseudoniscus roosevelti *Clarke*
Eurypterus pittsfordensis *Sarle*
Hughmilleria socialis *Sarle*
H. socialis *var.* robusta *Sarle*
Pterygotus monroensis *Sarle*

Publications

During the past year the publications of the department have been two in number, Bulletins 49 and 52. The former contained various brief paleontologic papers as follows:

Trenton Conglomerate of Rysedorph Hill and its Fauna, by Rudolf Ruedemann.

Marcellus Limestones of Central and Western New York and their Fauna, by John M. Clarke.

Marcellus Limestones of Lancaster, Erie co., by Elvira Wood.

New Agelacrinites, by John M. Clarke.

Amnigenia as an Indicator of Fresh Water Deposits during the Devonic of New York, Ireland and the Rhineland, by John M. Clarke.

The latter comprised papers on the following topics:

Contact Lines of Upper Siluric Formations on the Brockport and Medina Quadrangles, by J. M. Clarke, Rudolf Ruedemann and D. D. Luther.

Paleontologic Results of the Areal Survey of the Olean Quadrangle, by John M. Clarke.

Potsdam Sandstone of the Lake Champlain Basin, by Gilbert van Ingen.

Graptolite Facies of the Beekmantown Formation in Rensselaer county, N. Y., by Rudolf Ruedemann.

Growth and Development of Goniograptus thureaui McCoy, by Rudolf Ruedemann.

Fossil Alga from the Chemung of New York, by David White.

A new Genus of Paleozoic Brachiopods, Eunoa, by John M. Clarke.

Stratigraphic Value of the Portage Sandstone, by D. D. Luther.

Paleozoic Seas and Barriers in eastern North America, by E. O. Ulrich and Charles Schuchert.

Indigene and Alien Faunas of the New York Devonic, by John M. Clarke.

The succession of faunas on the Salamanca quadrangle. The collections which had been made in the field during the survey of the Salamanca area were carefully studied and determined for use in the delineation of the formations on the map. These determinations were made in this office by Mr Charles Butts, who was occupied therewith during the early part of the year.

Cooperation with the state engineer and surveyor. By an arrangement made with the state engineer and surveyor, we have been able to avail ourselves of the services of Gilbert van Ingen, formerly instructor in geology at Columbia University. Mr van Ingen gives one half of his time to the official named and the other half is given to duties connected with this office. He has therefore been engaged in prosecuting investigations which he had previously begun on the Potsdam sandstone and the fauna of the Beekmantown limestone. This arrangement is a temporary one, and we can not hope for its continuance after the expiration of April next.

The areal and paleontologic maps of the Canandaigua and Naples quadrangles. In my last report I noted that these maps had been essentially completed, and that we have here endeavored to establish a more detailed subdivision of the formations than has before been attempted. During the past year these maps have been carefully revised and corrected, and some time was

spent by D. D. Luther in the office on this work. They are now in the hands of the engraver, and it is hoped that they will soon be available.

The fauna of the pyrite layer at the horizon of the Tully limestone. I reported last year that an investigation of this subject was under way, and I am gratified to be able to incorporate the results of this work in this report. The work has been carried forward at my suggestion by Dr F. B. Loomis, assistant professor of biology at Amherst College. Its interest lies in the fact that we have here to deal with conditions influencing organic associations at the sea bottom, which can be interpreted only by actual experiment or from the most careful results of recent investigations on the varying conditions in existing bodies of salt water. Certain factors prevailing during Paleozoic time have brought about a segregation of iron sulfid in the sea water, which has deposited itself in an almost continuous sheet over a distance of 100 miles along the edge from Canandaigua lake to Lake Erie. With it are involved multitudes of organic remains, all of them of extraordinarily diminutive size and yet, as Dr Loomis has shown, representing arrested and primitive phases of the profuse fauna which occupied the ground before these peculiar conditions set in. This important fact being determined, namely that the fossils are only modified stages or conditions of the organisms which prevailed in that sea, the theorem is to demonstrate the character of the sea which could produce such a deposit. It has been usual to regard black bituminous shales, which generally carry large quantities of such pyrite deposits, as indicative of shallow or foul waters where decomposition has gone on with so much freedom as to produce directly much carbonate of iron and thus indirectly the sulfid. It is not however certain that we are correct in a conclusion of this kind, as recent studies of confined bodies of sea water, for example the Black sea, have indicated that separation of the sulfid is largely due to bacteria acting on the animal remains, but this is a process which takes place in the great depths where the bottom is covered with black mud, so that by comparison, such pyrite deposits, together with the black bituminous shales with which they are usually associated,

indicate a greater rather than a lessened depth of the sea. It is an illustration of one of the constantly increasing instances in which the paleontologist must be armed for the proper interpretation of ancient physiography with the growing volume of facts derived from the study of existing conditions.

Personnel of the staff

The permanent staff of this department has been changed during the year only in consequence of the death of George B. Simpson, draftsman; slight alterations have been made in the title of two of the assistants. The staff is as follows:

R. Ruedemann, assistant state paleontologist
D. D. Luther, field assistant
George S. Barkentin, draftsman
Philip Ast, lithographer
Jacob Van Deloo, clerk
H. S. Mattimore, preparator
Martin Sheehy, machinist

The following men have been temporarily engaged in the work of the department:

Prof. Charles Butts, on the fossils of the Salamanca quadrangle;

Prof. A. W. Grabau, on the survey of Becraft mountain;

Gilbert van Ingen, on various special topics as above stated;

C. A. Hartnagel, on the study of the Cobleskill limestone and its fauna;

Myron L. Fuller and F. G. Clapp, of the United States Geological Survey, in field work on the Elmira quadrangle.

W. S. Barkentin, Ruth Holden and Mary M. Mitchell have also assisted with the work of illustration.

Respectfully submitted

JOHN M. CLARKE
State Paleontologist

Oct. 1, 1902

PHILIP AST

1839-1903

With sincere sorrow I chronicle the death, May 8, 1903, of Philip Ast, who has been engaged in the work of this department for a period of more than 32 years.

Mr Ast was of German birth and his early training was that of the Latin school and gymnasium of his home town in Bavaria. At the age of 16 he entered the Bavarian army and served as an officer therein in the War of 1866 between Prussia and Austria. In 1870 he came to America. Mr Ast had a keen artistic sense and remarkable calligraphic facility but in what was to be the work of his life he had had neither experience nor knowledge. On his arrival in New York he secured employment with the well known lithographic establishment of Julius Bien & Co. and so successful were his first attempts there that when Prof. James Hall, needing a lithographer for the execution of the plates of the *Palaeontology of New York*, applied to Mr Bien, Mr Ast was sent to Albany to take up this work though his experience was then of but a few weeks' standing.

Free from the usual crudities of inexperience his efforts were from the start successful and demonstrated not merely an aptitude but a genius for the work. His activity in this career which has highly distinguished the illustrative work of this institution, began Ap. 1, 1871. The hundreds of lithographic plates of scientific objects executed by him remain as a record of his accomplishments, in the production of which he attained an adeptness and excellence which has never been elsewhere achieved in this country and few European workers have equaled his results for accuracy of delineation, perfection of finish and effect. His work raised the plates of the *Palaeontology of New York* to models of lithographic execution and exactitude.

An artist on stone is at the mercy of the printer, and sometimes a printer not over expert or none too conscientious has qualified the appearance of the imprints in a degree mortifying to the proper pride of the artist, but every lithographer comes to look with a sort of fatalistic toleration on such loss of the

more delicate beauties of his achievement. It is right to say that these finer results of Mr Ast's workmanship were never reproduced, were always sacrificed in some degree and their real beauties were known only to those who saw the stones before they left his hands.

Mr Ast was a man of keen interests and intelligent appreciations, kindly, true, loyal and generous. His life work was well done, and ended in his prime without a shade of departure from his standard. To such a servant, science in the State of New York owes no small debt.

J. M. C.

APPENDIX 1

ACCESSIONS

I herewith submit the list of accessions to the collections made during the year, and, in continuation of the record of fossiliferous localities, parts of which have been communicated in the last three reports, the additional localities entered during the course of the past year's work [Appendix 2].

The additions to the paleontologic collections have been by donation, purchase and collection. A detailed statement of these acquisitions is given herewith.

Donations

Wilson, J. D., Syracuse		
Gyroceras transversum	1	
Macrochilina onondagensis	1	(type)
Mesothyra?		
Agoniatite limestone, Manlius		
Dakin, G. A., Syracuse		
Gomphoceras sp.?	1	
Agoniatite limestone, Manlius		
Wood, Elvira, Waltham Mass.		
Fossils from the Stafford limestone, Lancaster, Erie co.		
Onychochilus nitidulus	1	(hypotype)
Lunulicardium fragile	2	(hypotypes)
Leptodesma marcellense	2	(hypotypes)
Chonetes scitulus	2	(hypotypes)
Camarotoechia prolifica?	1	(hypotype)
C. pauciplicata Wood	2	(types)
Grant, C. C., Hamilton Ont.		
Fossils from the Niagaran at Hamilton	70	
Fossils from the Clinton at Hamilton	3	
Barry, S. F., Sup't Penrhyn Slate Co., Middle Granville		
Four large slabs bearing 69 specimens of Dactyloidites bulbosus from the Lower Cambric, Middle Granville	4	

St John, Edward P., Hartford Ct. Coral from the Lower Chemung, Prattsburg	1	
Udden, J. A., Rock Island Ill. Sponge from the Lower Carboniferous, Henton, Mills co. Ia.	1	
Total by donation	92	(8 hypotypes, 3 types)

Purchases

Dolbel, A. F., Grande Grève Que.	
Three barrels of Grande Grève limestone fossils	900
Kranz, F., Bonn, Germany	
Fossil parasites	14
Woodward, A. S. and Sherborn, C. D.	
Fossils from the Tilestones of Ludlow Eng.	215
Hartley, Frank, Cumberland Md.	
Fossils from the lowest horizon of the Hamilton group on Williams road near Cumberland Md.	150
Calder, Donald, Thurso, Scotland	
Old Red sandstone flags, Thurso	20
Rae, John, Stromness, Orkney islands	
Old Red sandstone flags, Sandwick	19
Total by purchase	1318

Collections

The paleontologist	
Old Red sandstone, Cromarty, Scotland	55
Old Red sandstone flags, Stromness, Orkney	1
Ruedemann, R.	
Cambric graptolites, sponges and brachiopods at Schaghticoke	1650
Trenton fossils, Schuylerville	20
Cambric-Utica fossils collected in mapping Cohoes sheet	450

Ruedemann, R. and Luther, D. D.	
Fossils from the Guelph dolomites at Shelby	750
Luther, D. D.	
Fossils from Naples shales, Naples	78
Lower Chemung shales	35
Salina shales, Pittsford	20
Portage fossils from Erie and Chautauqua counties	772
Guelph fossils from Shelby	150
Mattimore, H. S. and Hartnagel, C. A.	
Fossils from the Upper Devonic outcrops on Elmira quadrangle	1200
Hartnagel, C. A.	
Collections from the Cobleskill limestone in Otsego, Schoharie and Ulster counties	1190
van Ingen, G.	
Lower Cambric, Middle Granville	20
Total by collection	6391
Total accessions	7801 (3 types, 8 hypotypes)

APPENDIX 2

NEW ENTRIES ON GENERAL RECORD OF LOCALITIES OF AMERICAN PALEOZOIC FOSSILS BELONGING TO THE STATE MUSEUM

ALPHABETIC LIST OF LOCALITIES

Albany (Albany co.), 3205, 3221
Angola (Erie co.), 3098, 3099, 3100, 3101, 3102
Bath (Rensselaer co.), 3220
Big Sister creek (Erie co.), 3103, 3104
Bird creek (Chemung co.), 3177
Bradnor Hill, Kingston Eng., 112 (yellow ticket)
Bradnor Lane, Kingston Eng., 120 (yellow ticket)
Brindgwood Chase Eng., 113, 114 (yellow ticket)
Brunswick (Rensselaer co.), 3213
Carr hill (Chemung co.), 3164
Catlin (Chemung co.), 3168, 3169, 3170
Christian hollow (Chemung co.), 3171, 3172, 3173, 3174
Corning (Steuben co.), 3142, 3143
Deep kill (Rensselaer co.), 3206, 3207, 3211, 3223
Downton, England, 121 (yellow ticket)
East Corning (Steuben co.), 3165, 3167, 3190, 3191
Eighteen Mile creek (Erie co.), 3103, 3104
Elmira (Chemung co.), 3147, 3148, 3149, 3155, 3156, 3171, 3172, 3186, 3187, 3188, 3189, 3192, 3193, 3194, 3198
Farnham creek (Erie co.), 3101
Faulkner's ravine (Chautauqua co.), 3105, 3106, 3109
Fitch bridge (Chemung co.), 3146
Forestville (Chautauqua co.), 3113, 3114, 3115, 3116, 3117, 3118, 3120, 3121
Fruing's Que., 3094
Grant Hollow (Rensselaer co.), 3216
Hamilton Ont., 3127, 3128
Hargeest Mill, Kingston Eng., 122 (yellow ticket)
Hawley hill (Chemung co.), 3149
Hendy creek (Chemung co.), 3186, 3187, 3188, 3189
Horseheads (Chemung co.), 3152, 3153, 3154, 3155, 3156, 3163
Johnson hollow (Chemung co.), 3130, 3132, 3139, 3199, 3200, 3201

NEW YORK LOCALITIES ACCORDING TO COUNTIES

(Names in italic are new to the record)

INDEX TO FORMATIONS

3194, 3195, 3196, 3197, 3198, 3199, 3200?, 3201

Laona sandstones, 3105, 3106, 3109

RECORD OF LOCALITIES

3094 Grande Grève limestone. Fruing's, Quebec, Can. A. F. Dolbel, collector. 1902.

3095 Trenton limestone. Loose block at roadside west side of Prospect hill, 1½ miles southeast of Keeseville, Essex co. N. Y. Station 150 C3. G. van Ingen, collector. 1901.

3096 Portage (Cashaqua) shales. Pike creek, Erie co. Top of Cashaqua shales. D. D. Luther, collector. 1902.

3097 Portage shales. Lower black band near mouth of Pike creek, Erie co. D. D. Luther, collector. 1902.

3098 Portage shales. Angola, Erie co.; lake shore. Horizon, top of second black band. D. D. Luther, collector. 1902.

3099 Portage shales. Angola; under Lake Shore railroad bridge. Horizon of big goniatites. D. D. Luther, collector. 1902.

3100 Portage shales. Base of second gray band. Angola. D. D. Luther, collector. 1902.

3101 Portage shales. Angola; lake shore, mouth of Farnham creek. D. D. Luther, collector. 1902.

3102 Portage shales. Angola. Big Sister creek near mill; 25 feet above top of second black band. D. D. Luther, collector. 1902.

3103 Portage (Cashaqua) shales. Eighteen Mile Creek; North Evans. Mostly from concretions. D. D. Luther, collector. 1902.

3104 Portage shales. Eighteen Mile creek; North Evans. Base of second black band. D. D. Luther, collector. 1902.

3105 Chemung beds. Faulkner's ravine 2½ miles south of Smith's Mills. From the (Laona) sandstones. D. D. Luther, collector. 1902.

3106 Chemung beds. Faulkner's ravine, 1½ miles north of Nashville, Chautauqua co. The (Laona) sandstones. D. D. Luther, collector. 1902.

3107 Chemung beds. Sixteen Mile creek; Northeast Pa., From an exposure along the brook that flows through the southern part of village, at a point about ¼ of a mile from Lake Erie and 25 feet above lake level. Surface of flags. D. D. Luther, collector. 1902.

3108 Chemung beds. In the gorge at Shumla, Chautauqua co. A few Orthis and Productella occur in several layers. D. D. Luther, collector. 1902.

3109 Chemung beds. Smith's Mills, Chautauqua co., 3 miles south of, on road to Nashville. Faulkner's ravine; branch of Silver creek. The (Laona) sandstone. D. D. Luther, collector. 1902.

3110 Portage. Roadside 1½ miles west of Smith's Mills. D. D. Luther, collector. 1902.

3111 Portage. Ravine ½ mile west of Smith's Mills. D. D. Luther, collector. 1902.

3112 Portage. Smith's Mills; 15 feet below the row of concretions in ravine east of hotel. D. D. Luther, collector. 1902.

3113 Chemung or Ithaca beds. Ravine ½ mile east of Forestville, Chautauqua co.; about 100 feet above sandstone, second fossiliferous layer above sandstone. D. D. Luther, collector. 1902.

3114 Chemung or Ithaca beds. Ravine east of Forestville. From thin calcareous layer about 50 feet above sandstone. D. D. Luther, collector. 1902.

3115 Portage. Forestville; below railroad bridge. D. D. Luther, collector. 1902.

3116 Portage. Forestville. Above railroad bridge and below mill; from concretions on Walnut creek gorge. D. D. Luther, collector. 1902.

3117 Chemung or Ithaca beds. Forestville; Terry's ravine. From the sandstone at top of falls. D. D. Luther, collector. 1902.

3118 Portage. Forestville; Terry's gully; 50 feet below sandstone. D. D. Luther, collector. 1902.

3119 Chemung or Ithaca beds. Forestville; Terry's ravine. Horizon of the sandstone. D. D. Luther, collector. 1902.

3120 Chemung beds. Forestville. From the sandstone on Walnut creek. D. D. Luther, collector. 1902.

3121 Chemung beds. Forestville. Small ravine in heart of village; about 50 feet above sandstone. D. D. Luther, collector. 1902.

3122 Lower Guelph dolomite. Oak Orchard creek, ½ mile south of Shelby. R. Ruedemann and D. D. Luther, collectors. 1902.

3123 Shaly limestone 8 to 10 feet above Lower Guelph dolomite. Shelby. D. D. Luther, collector. 1902.

3124 Lockport limestone below Upper Guelph dolomite along Oak Orchard creek, about 2 miles south of Shelby. R. Ruedemann and D. D. Luther, collectors. 1901 and 1902.

3125 Upper Guelph dolomite exposed along Oak Orchard creek about 2 miles south of Shelby. R. Ruedemann and D. D. Luther, collectors. 1901 and 1902.

3126 Georgian. Dactyloidites from black slate overlying the "flint" bed in the first quarry of the Penrhyn Slate Co.'s quarries at Middle Granville, Washington co. N. Y. Penrhyn Slate Co., Granville N. Y., donor and G. van Ingen, collector. 1902.

3127 Niagaran. Hamilton Ont. C. C. Grant, donor. 1902.

3128 Clinton beds. Hamilton Ont. C. C. Grant, donor. 1902.

3129 Trenton drift. Winona Ont. C. C. Grant, donor. 1902.

FOSSILS COLLECTED BY C. A. HARTNAGEL AND H. S. MATTIMORE IN AREA COVERED BY THE ELMIRA QUADRANGLE, CHEMUNG AND STEUBEN COUNTIES, 1902. LOCALITY NUMBERS 3130–3201 INCLUSIVE

3130 Chemung beds. Johnson hollow, ¾ mile northwest of Lower Pine Valley, Chemung co. (A^1 1324 ft A. T.)

3131 Chemung beds. Johnson hollow; northeast escarpment of 1500 foot hill ¾ of a mile northwest of Lower Pine Valley. (A^2 1277 ft A. T.)

3132 Chemung beds. A short distance southeast of 3131. (A^3 1272 ft A. T.)

3133 Chemung beds. Along road 1½ miles west of Millport, Chemung co. (B^1 1215 ft A. T.)

3134 Chemung beds. About 100 yards south of 3133; fossiliferous layer. (B^2 1190 ft A. T.)

3135 Chemung beds. In creek bed at small falls, about ¾ mile northwest of Pine Valley, Chemung co. (C^1 1045 ft A. T.)

3136 Chemung beds. Outcrop on northeast side of road 1 mile northwest of Pine Valley. (C^2 1100 ft A. T.)

3137 Chemung beds. Outcrop a short distance north of 3136. (C^3 1135 ft A. T.)

3138 Chemung beds. In creek bed at high falls, about 1½ miles northwest of Pine Valley. (C^4 1260 ft A. T.)

3139 Chemung beds. Outcrop along roadside on road running southwest from Johnson hollow, 2 miles northwest by west from Lower Pine Valley. (C^5 1600 ft A. T.)

3140 Chemung beds. About 1½ miles north of Post Creek, Chemung co., along road running parallel to the east of Fall Brook railroad. (D^1 1260 ft A. T.)

3141 Chemung beds. Top of hill about 1½ miles north of Post Creek. (D^2 1480 ft A. T.)

3142 Chemung beds. Along road running parallel to Fall Brook railroad, 1½ miles northeast of Corning, Steuben co. (E^1 900 ft A. T.)

3143 Chemung beds. 100 yards northeast of 3142. (E^2 900 ft A. T.)

3144 Chemung beds. On northwest road running at right angles to Post Creek road, 1 mile southwest of Post Creek; ¾ of a mile from junction of roads. (F^1 1280 ft A. T.)

3145 Chemung beds. 2½ miles southwest of Post Creek, up ravine running north from road. (F^2 1250 ft A. T.)

3146 Chemung beds. Road running parallel to and on north side of Chemung river, ½ mile west of Fitch bridge, Chemung co. (G^1 945 ft A. T.)

3147 Chemung beds. In creek bed along ravine running north from river, 5 miles west of Elmira. (G^2 1080 ft A. T.)

3148 Chemung beds. On roadside along ravine and 2¼ miles north of 3147. (G^3 1080 ft A. T.)

3149 Chemung beds. Quarry on Hawley hill, 3½ miles northwest by west of Elmira. (G^4 1740 ft A. T.)

3150 Chemung beds. Creek bed in ravine running northwest from Pine Valley road, 1 mile north of Pine Valley. (H^1 1070 ft A. T.)

3151 Chemung beds. Farther up same ravine as 3150. (H^2 1100 ft A. T.)

3152 Chemung beds. Quarry 1 mile east of Horseheads, Chemung co. (I^1 1100 ft A. T.)

3153 Chemung beds. Outcrops south side of east and west ravine, 1½ miles east of Horseheads. (I^2 1320 ft A. T.)

3154 Chemung beds. In road bed near eastern end of quadrangle, 3 miles east of Horseheads. (I^3 1480 ft A. T.)

3155 Chemung beds. Outcrop on north side of road running parallel to Latty brook, 1½ miles south of road between Elmira and Horseheads. (I^4 1085 ft A. T.)

3156 Chemung beds. In creek bed running north from Latty brook, 1½ miles east of road between Elmira and Horseheads. (I^5 1160 ft A. T.)

3157 Chemung beds. 1½ miles west of New York, Lake Erie & Western railroad in creek bed of first ravine running west, south of North Elmira. (J^1 1025 ft A. T.)

3158 Chemung beds. 50 yards above 3157 in small ravine leading from the north to main creek. (J^2 1050 ft A. T.)

3159 Chemung beds. In quarry in ravine leading north from 3157, about 200 yards from road. (J^3 1080 ft A. T.)

3160 Chemung beds. Creek bed ¼ mile southwest of 3158. (J^4 1090 ft A. T.)

3161 Chemung beds. Outcrop in road 3 miles southeast of Pine Valley. (K^1 1000 ft A. T.)

3162 Chemung beds. Side of ravine running parallel to and ½ mile north of 3161. (K^2 1060 ft A. T.)

3163 Chemung beds. Quarry west of Pine Valley road, 2 miles north of Horseheads. (K^3 940 ft A. T.)

3164 Chemung beds. Ravine west of Pine Valley road on east side of Carr hill. (K^4 1120 ft A. T.; K^5 1120 ft A. T. 100 yards north of K^4)

3165 Chemung beds. In bed of Winfield creek near highway, 1½ miles north of East Corning, Steuben co. (L^1 1050 ft A. T.)

3166 Chemung beds. In bed of Winfield creek, about 200 yards above 3165. (L^2 1070 ft A. T.)

3167 Chemung beds. Creek bed 2½ miles northeast of East Corning. Boundary line of Steuben-Chemung co. (L^3 1150 ft A. T.)

3168 Chemung beds. In bed of Madison creek, 1 mile northwest of Catlin, Chemung co. (M^1 1150 ft A. T.)

3169 Chemung beds. In bed of Madison creek, 1½ miles northwest of Catlin. (M^2 1225 ft A. T.)

3170 Chemung beds. In road bed, 2¼ miles northwest of Catlin; crest of hill near three corners. (M^3 1640 ft A. T.)

3171 Chemung beds. In Christian hollow, Chemung co., 4¼ miles southwest of Elmira; from hillside west of creek. (N^1 1040 ft A. T.)

3172 Chemung beds. In Christian hollow, ½ mile above 3171. (N^2 1080 ft A. T.)

3173 Chemung beds. In Christian hollow at Rosstown, Chemung co. (N^3 1120 ft A. T.)

3174 Chemung beds. From lower quarry at Rosstown; 50 feet above 3173. (N^4 1170 + ft A. T.)

3175 Chemung beds. From hard limestone layers of upper quarry at Rosstown. (N^5 1300 + ft A. T.)

3176 Chemung beds. From hard projecting rock (limestone) in roadbed, 1 mile southwest of Rosstown, near summit of hill. (N^6 1650 ft A. T.)

3177 Chemung beds. Creek bed, Bird creek, 1½ miles south of Wells, Chemung co. (N^7 1150 ft A. T.)

3178 Chemung beds. In creek bed, 1½ miles west of Pine City, Chemung co. (O^1 1200 ft A. T.)

3179 Chemung beds. In creek bed 200 yards below 3178. (O^2 1160 ft A. T.)

3180 Chemung beds. In creek bed, ¼ of a mile below 3178. (O^3 1140 ft A. T.)

3181 Chemung beds. Creek bed, 100 yards below 3180. (O^4 1130 ft A. T.)

3182 Chemung beds. Quarry near highway bridge, 1½ miles slightly northwest of Pine City. (O^5 1200 ft A. T.)

3183 Chemung beds. Creek bed, 100 yards above highway bridge, 1½ miles slightly northwest of Pine City. (O^6 1165 ft A. T.)

3184 Chemung beds. Creek bed, ¾ of a mile west of Pine City. (O^7 1090 ft A. T.)

3185 Chemung beds. Quarry ¾ of a mile southwest of Pine City along Seeley creek. (O^8 1120 ft A. T.)

3186 Chemung beds. Bed of Hendy creek, 5 miles west of Elmira. (P^1 960 ft A. T.)

3187 Chemung beds. Bed of Hendy creek, ½ a mile above 3186. (P^2 980 ft A. T.)

3188 Chemung beds. Quarry 1 mile above 3187; back from creek to south, in hillside. (P^3 1200 ft A. T.)

3189 Chemung beds. Bank of Hendy creek, 6¾ miles west of Elmira. (P^4 1220 ft A. T.)

3190 Chemung beds. In creek bed just off west edge of quadrangle, 2 miles southwest of East Corning, Steuben co. (P^5 1100 ft A. T.)

3191 Chemung beds. In creek bed, 1/3 of a mile below 3190; short distance below point where creeks join. (P^6 1070 ft A. T.)

3192 Chemung beds. Roadside on Mt Zoar road, 3 miles southwest of Elmira. (Q^1 1140 ft A. T.)

3193 Chemung beds. Roadbed nearly ¾ of a mile southwest of 3192.

3194 Chemung beds. Roadbed near summit of Mt Zoar, 5 miles west of Elmira. (Q^3 1740 ft A. T.)

3195 Chemung beds. Roadbed 1¾ miles west of Mt Zoar. (Q^4 1720 ft A. T.)

3196 Chemung beds. Roadbed 1 mile southwest of 3195, near three corners. (Q^5 1680 ft A. T.)

3197 Chemung beds. Bank of creek 3 miles southwest of Pine City; nearly ½ a mile north of Mudlick creek. (Q^6 1150 ft A. T.)

3198 Chemung beds. Quarry 3 miles southwest of Elmira; quarry in hillside ½ a mile off road between Pine City and Southport, Chenango co. (Q^7 1100 ft A. T.)

3199 Chemung beds. Johnson hollow; 10 feet below 3132. (A^4 1262 ft A. T.)

3200 Hamilton? Johnson hollow; loose boulder. (A^5 900 ft A. T.)

3201 Chemung beds. Creek bed along Johnson hollow. (A^6 920 ft A. T.)

3202 Trenton (Normans kill) shale. Road cut 100 yards south of Winne's hotel, north of Lansingburg, Rensselaer co. R. Ruedemann, coll. 1901.

3203 Utica shale. Outcrop along Hudson river below dam at Mechanicville, Saratoga co. R. Ruedemann, coll. 1901.

3204 Utica shale. Shale on eastern river bank 2 miles north of Lansingburg. R. Ruedemann, coll. 1901.

3205 Upper Utica shale. Creek south of Ward's lane north of Albany, Albany co. H. C. Wardell, coll. 1901.

3206 Lorraine. Mouth of Deep kill, Rensselaer co. R. Ruedemann, coll. 1901.

3207 Lorraine. Outcrop on east bank of Hudson river at the rapids of the river, ½ mile south of mouth of Deep kill, Rensselaer co. R. Ruedemann, coll. 1901.

3208 Trenton (Normans kill) indurated cherty shale. Cut on river road 200 yards north of stable of United Traction Co. at Lansingburg, Rensselaer co. R. Ruedemann, coll. 1901.

3209 Utica shale. Cut on Fitchburg railroad, ½ mile south of Melrose station, Rensselaer co. R. Ruedemann, coll. 1901.

3210 Georgian. Black fossiliferous shales, below bridge of Speigletown — Lansingburg road over Wilson's creek, Rensselaer co. R. Ruedemann, coll. 1902.

3211 Lower Siluric. Fossiliferous limestone bed, Deep kill, Rensselaer co., 100 yards above culvert of Fitchburg railroad. R. Ruedemann, coll. 1902.

3212 Trenton (Normans kill) shale. Railroad cut, northeast of Schuylerville, Saratoga co.; cut on Fitchburg railroad. R. Ruedemann, coll. 1902.

3213 Trenton (Normans kill) shale. Road, Lansingburg-Brunswick, Rensselaer co., above viaduct of Fitchburg railroad. R. Ruedemann, coll. 1902.

3214 Trenton (Normans kill) shale. Shaft 4 of tunnel of Troy waterworks extension on Tomhannock creek, Rensselaer co. R. Ruedemann, coll. 1902.

3215 Trenton (Normans kill) shale. Shaft 1 of tunnel of Troy waterworks extension on Tomhannock creek, Rensselaer co. R. Ruedemann, coll. 1902.

3216 Georgian. Fossiliferous shale 1½ miles northeast of Grant Hollow, on Bohnstiel farm, Rensselaer co. R. Ruedemann, coll. 1902.

3217 Trenton (Normans kill) shale. Fossiliferous shale, 1 mile northeast of Speigletown, Rensselaer co., on hill slopes east of Speigletown-Melrose road, on C. D. Chapman farm. R. Ruedemann, coll. 1902.

3218 Trenton (Normans kill) shale. Road cut a little west of junction of Speigletown-Raymertown and Melrose-Raymertown roads, Rensselaer co. R. Ruedemann, coll. 1902.

3219 Trenton (Normans kill) shale. Fossils from three localities lying in the strike of the rocks extending for several miles south-southwest of shaft 1 of tunnel of Troy waterworks extension, Rensselaer co. R. Ruedemann, coll. 1902.

3220 Lowest Utica shale. From quarry near pumping station at Bath, Rensselaer co.; dredged from Hudson river at Troy. R. Ruedemann, coll. 1902.

3221 Upper Utica beds. Menands, Albany co. From trenches dug for laying water mains along Troy-Albany road. R. Ruedemann, coll. 1902.

3222 Trenton (Normans kill) shale. Outcrop on road from Johnsonville to Tomhannock, 1 mile southwest of Johnsonville, Rensselaer co., in front of farm of Frank Viele. R. Ruedemann, coll. 1902.

3223 Utica shale. Along north branch of Deep kill, west of Melrose, Rensselaer co. R. Ruedemann, coll. 1902.

3224 Trenton (Normans kill) shale. Station 201. Gravel pit on road near home of N. Cottrell, 2 miles southeast of Tomhannock, Rensselaer co. R. Ruedemann, coll. 1902.

3225 Trenton (Normans kill) shale. Station 160. Gravel pit in front of schoolhouse, 1 mile south of Johnsonville, Rensselaer co. R. Ruedemann, coll. 1902.

3226 Trenton (Normans kill) shale. Station 138. Outcrops on ridge, 1¼ miles due north of Tomhannock, Rensselaer co. R. Ruedemann, coll. 1902.

3227 Trenton (Normans kill) shale. Station 167. Outcrops on farm of D. Esmond, 2 miles north of Tomhannock, Rensselaer co. R. Ruedemann, coll. 1902.

3228 Cambric slates. Station 49. Outcrop on west side of Lansingburg-Speigletown road, ½ mile southwest of Speigletown, Rensselaer co. R. Ruedemann, coll. 1902.

3229 Upper Cambric slates. (Dictyonema bed). Gorge of Hoosick river at Schaghticoke, Rensselaer co. R. Ruedemann, coll. 1902.

3230 Upper Cambric slates. (Clonograptus bed). Gorge of Hoosick river at Schaghticoke. R. Ruedemann, coll. 1902.

RECORD OF FOREIGN LOCALITIES

Specimens bearing lemon-yellow tickets

108 Top of Tilestones. Ludlow Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

109 Top of Upper Ludlow. Ludlow Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

110 Upper Ludlow. Whitecliffe Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

111 Upper Ludlow. Ludford Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

112 Upper Ludlow. Bradnor Lane, Kingston Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

113 Base of Upper Ludlow. Bringdwood Chase Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

114 Ludlow. Bringdwood Chase Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

115 Passage beds. Ludlow Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

116 Upper Ludlow. Onibury Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

117 Downtonian. Waterworks, Ludford Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

118 Downtonian. Ludford Lane Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

119 Upper Ludlow. Ludlow Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

120 Downtown sandstone. Bradnor Hill, Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

121 Upper Ludlow. From one of the hard nodular bands, 2 miles west of Ludlow on road to Downton Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

122 Downton sandstone. Hargeest Mill, Kingston Eng. A. S. Woodworth and C. D. Sherburne, collectors. 1902.

123 Ludlow Bone bed. Ludford Lane Eng. A. S. Woodward and C. D. Sherburne, collectors. 1902.

THE DWARF FAUNA OF THE PYRITE LAYER AT THE HORIZON OF THE TULLY LIMESTONE IN WESTERN NEW YORK

BY F. B. LOOMIS

Plates 1–5

Recent determinations by the state paleontologist have shown that the Tully limestone which in central New York caps the Hamilton shales in its westward extension, feathers close to the east shore of Canandaigua lake, and from there westward to Lake Erie its place in the stratigraphic succession is marked by a thin sheet of pyrite from 1 to 4 inches in thickness. This pyrite deposit is often continuous for considerable distances, appearing in the strike at certain localities without break for a length of one to a few rods, and when interrupted it is only for a short interval. It may be looked on as an essentially continuous mantle, always maintaining its stratigraphic position between the calcareous Hamilton and the bituminous Genesee shales. It is a deposition synchronous with and in continuation of the Tully limestone in a region where that formation is no longer represented by limestone sedimentation, where indeed bathymetric conditions did not permit the deposition of such a sediment. The highly bituminous deposits of the Genesee sea indicate befouled waters where organic decomposition was extensively under way. The inception of these conditions is strongly expressed by the presence of the pyrite sheet 100 miles in extent on the strike; and in fact a similar indication is presented by the Tully limestone itself, which for some extent along its feathering edge carries considerable quantities of pyrite.

The fauna of the Tully limestone is essentially a congeries of Hamilton species, but, added thereto, it contains the well known and far scattered brachiopod Hypothyris cuboides Sowerby, which has been called by Hall Rhynchonella venustula. *For more than 50 years this species has been recognized as an index of early Upper Devonic time,* and this diagnosis of its time value is supplemented by certain established mutations of earlier species. The Tully limestone thus represents the opening stage of Upper Devonic time in the New York succession.

The Tully pyrite contains a fauna so diminutive that it escapes ordinary observation; so simple that it seems like a group of young forms; and so unlike the usual species of the limestone that without definite knowledge of its horizon it would be difficult to locate its stratigraphic position. Few of the specimens are over 2 mm in diameter, but are adults. The fauna is rich, including Crustacea, Cephalopoda, Lamellibranchiata, Gastropoda, Brachiopoda, and Crinoidea; corals failing entirely.

This fauna was first noticed by J. M. Clarke in 1885,[1] who recorded 12 species, describing 11 of them as new; and suggested that there was abundant opportunity to enlarge the fauna. Two years ago, Dr Clarke placed some of the pyrite matrix from Canandaigua lake in my hands, and later more from other localities. In all the regions represented by this material, life was abundant, a cubic inch of rock rarely furnishing less than two or three fossils; but, on account of the small size, they are difficult to find and more difficult to remove, as the matrix is extremely hard and tenacious.[2]

So far as we have made it out, the fauna consists of 51 species,[3] mostly less than 2 mm in diameter. These are distributed as follows: 40 from Canandaigua lake, 33 from the Livonia salt shaft (at a depth of 280 feet), 27 from Greigsville, 25 from Little Beard's creek near Moscow, and 19 from near the Delaware, Lackawanna & Western Railroad at Moscow N. Y. The greater number from the first two localities is due partly to the fact that more rock from these was broken up, and partly because they are richer in specimens. The shells of most of the Brachiopoda have a distinctly Prehamilton appearance, doubtless due in some measure to their arrested condition of growth. Many of the gastropods and cephalopods have also such an aspect; but along with such shells are occasional larger representatives,

[1] U. S. Geol. Sur. Bul. 16. 1885. p. 28.

[2] The only successful method devised for removing the fossils is to roast the pyrite some time over a blue flame, and then plunge in cold water. Without roasting, the matrix will not come away from the fossils, but breaks through them. After roasting, however, the pyrite cleaves away, and with a lens the tiny forms may be found.

[3] Two more species were found, but lost in trying to prepare them more completely for drawing.

which approach closer to the usual expression of the Hamilton species below, and from a gradation between the dwarfs and the normal Hamilton forms. As these species are unquestionably immediately descended from Hamilton ancestors, they are here considered as variations from the normal Hamilton species, and are described as *mutations.* This term is used not only in the common acceptance of the word, but within the meaning is incorporated the conception that the species have arisen under abnormal conditions. This seems to me preferable to calling them new species, though the variation is considerable in many cases. The resultant forms are such as might have arisen from a laboratory experiment. On considering the small size and the simple ornamentation of the specimens, the first suggestion is that they are young. But a whole fauna can not exist of immature forms alone. There is further a uniformity in the size of the individuals of each species, which can only express adult growth. The Goniatites indicate this with clearness; here are over 100 representatives, all apparently of one species, each a perfect miniature Goniatites with three whorls and 25 or more chambers, the whole no larger than the primitive three whorls of the normal species of Goniatites, from which they are evidently derived. The Brachiopoda specially show uniformity in the development of size; a valve with 10 or 11 ridges and furrows, with septum, muscular impressions and several lines of growth, will not be more than two or three times as large as the protegulum of the same species from the Hamilton. The specimens are nevertheless essentially adults, so far as their relation to the congeries as a whole is concerned, though having usually only about one fifteenth the diameter of their progenitors.

The fauna is not uniformly dwarfed, large specimens occasionally occuring among the otherwise tiny forms. Some groups of species are more affected than others. The dwarfing agent has totally eliminated the corals; the Brachiopoda are most uniformly and extensively dwarfed; the Lamellibranchiata are much affected; the Gastropoda and Cephalopoda are mostly tiny, but also have some medium and occasionally large sized representatives, all adults.

Such is the peculiar fauna, and in the study of it we are led to seek (1) the cause of this dwarfing, (2) the reason for the lack of uniformity of effect, (3) the length of time the fauna has been acted on by dwarfing agents, (4) the modifications effected both in shape and size.

In considering whether water impregnated with iron and sulfur variously oxidized can dwarf without annihilating a fauna, I may cite other instances of faunas similarly affected by the medium. The oolitic hematite iron ore band of the Clinton beds extends from central New York westward to Wisconsin and south to Alabama, is at many localities highly fossiliferous, and according to Smyth[1] it was laid down in water carrying an excess of iron in solution. Observations made by the writer on the fossils of this layer obtained at Rochester N. Y. show that these species have an average of about one third the diameter of the same species in the beds just above and below. The dwarfing, in this case, can not be attributed to anything but the iron in the water, acting as an unfavorable environment. Linney[2] notices the same dwarfing in this layer in Kentucky. To verify this dwarfing effect of iron in solution or suspension, experiments were made on small fishes, tadpoles and snails in aquarium water saturated with iron; and kept beside control aquariums, the fish, etc., in both cases being fed all they would take. After eight months in this iron water, the fish and tadpoles had lost from 3 mm to 5 mm in length.[3] Their habits had also undergone considerable change.[4] It is well known that certain species of fishes living in the freshened Baltic sea are much smaller than the same species in the Arctic ocean.[5] Herbst[6] and others, experimenting on embryos in water with various chemicals, get dwarfed and abnormal results; these however have not lived on to adult condition. In all these cases, and in many

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[1] Am. Jour. Sci. 1892. 143:487.

[2] Report of Bath county, Ky.

[3] This experiment was carried on by Messrs Burrows, A. C. Kretchmar and Southgate in the biologic laboratory of Amherst College.

[4] While the results in the above experiment are not large, they show the dwarfing effects of iron; and on animals born in the iron waters, the effect would be much greater, as in embryonic life they are more sensitive.

[5] See Gunther. Introduction to the Study of Fishes, p. 204.

[6] Zeitschr. f. Wissenschaftl. Zoologie. 1892. v. 55. *See also* Wilson. The Cell. 1896. p. 323.

others which might be cited, an unfavorable medium has caused dwarfing among the animals inhabiting it, and in the above instances the media have been modified by an unusual chemical change.

Such was also the case in the sea in which the Tully pyrite was formed. It was a shallow water area, perhaps landlocked in a measure and undoubtedly running shoreward into low coastal marshes. Its waters were surcharged with iron in solution, probably a ferrous carbonate; and over its bottom was a profusion of decaying organic matter. Such decaying matter would give off sulfuretted hydrogen.[1] We have here two chemical agents at work, either separately or in combination, either of which would be an unfavorable element in the environment. There is very little if any distortion among these species. The dwarf condition may be attributed either to the presence of the iron, to the gases escaping from decomposition or to both. The pyrite is an insoluble compound and represents the precipitate formed by the iron and the gases of decomposition. The dwarf condition is coextensive with the deposit of iron. It is perhaps not surprising that these forms should be dwarf, but that they could live and retain their characters enough to make them recognizable while attaining only one fifteenth their normal size, is noteworthy.

The reaction which would deposit pyrite in such a sea is familiar. The iron, as ferrous carbonate, would unite with the sulfuretted hydrogen to form pyrite, carbonic dioxide gas and water ($FeCO_3+2(H_2S)+O=FeS_2+CO_2+2(H_2O)$. There are probably more steps in the process than the formula indicates, but the end results would be as stated. In the pyrite, as it has formed by precipitation, the fossils have been ingulfed, having died on the spot where they are found. This is evident from the fact that the bivalves when preserved, have both valves intact, which would not be so likely to occur if the shallow sea had been exposed to the play of the waves. The iron-carrying waters were not entirely disconnected from the purer waters of the sea without, for into these pyrite faunas come occasional representatives of

[1] Dr Dall tells me that occasionally after heavy rains H_2S is carried out into the waters along the coast of Florida, and that many animals are killed thereby, and others, which withstand the influence better, are distorted.

the more actively moving groups of animals, such as snails and cephalopods. A sea answering all the above conditions could not be an open extensive body of water, like an ocean, but must rather have been more of the nature of a great swamp, with its open lagoons and connecting passages. This condition would in a measure account for the deposition of pyrite in disconnected but not widely separated areas. The animals in the iron-bearing lagoons would feel the dwarfing effect; those outside would be free from such conditions; and occasionally a normal individual might readily drift in among the dwarf faunas.

The fossils in this collection represent three specific areas, one on Canandaigua lake, Ontario co., one about Livonia, Livingston co., and one near Moscow, Genesee co. Of these, the first two seem to have been more isolated, the last has frequent larger forms which have drifted into it. In all the areas, however, the degree of dwarfing is practically the same.

In considering the relative time required to produce this dwarf fauna, or to deposit the pyrite layer, it is clear that the greatest dwarfing would be accomplished by the chemical action on the embryos; and it is equally evident that the life of several generations would be necessary to reduce a species to one fifteenth of its normal size. One might expect, that in the lowest parts of this deposit, the first generations which had lived in the iron water would be larger, and that those above would be successively smaller, as they had been exposed longer to the unfavorable conditions. This is not, however, the case. The animals from the bottom of the pyrite are of the same size as those from the upper part. There seemed to be fewer individuals in the top than in the bottom part of the pyrite, but fossils were distributed all the way through. *Hence it appears that the first embryos to be affected by the iron are as much affected as were the following generations which were descended from those dwarfs.*[1] By the time these first dwarfs bred, they seem to have accustomed themselves to the abnormal environment, so that their progeny grew as large as the parents.

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[1] This is a proposition which requires verification; but at present I know of no experiment which has been carried through several generations and observation taken in regard to the growth under such unfavorable circumstances.

The effect on the organisms is of two kinds, first the dwarfing, and second the modification in form. The amount of dwarfing varies in each group, apparently according to the habits of the group. Iron in solution in water tends to settle gradually to the bottom, as was found in experimenting on the fishes, etc. in the aquariums. Thus the bottom layers of water are denser and more impure. The forms living wholly on the bottom are thus most affected. Therefore it is not surprising to find that the brachiopods, which are either sessile or lie on the bottom, are the most dwarfed. There is also great uniformity in the size of the individuals of a given species, due to their spending their whole life in the iron water. No single brachiopod has been found which was larger than the natural adult size for pyrite forms of that species. All the exceptions to the universal dwarfing occur in the other groups. The only period when the brachiopod is free swimming is during larval life; and, with the dwarfing beginning then and continuing all along, by the time the protegulum is formed, the animal is strikingly a pygmy. The adult brachiopods in the pyrite are seldom one fifteenth the diameter of the ancestral form. Lamellibranchs are also greatly modified, and show uniformity in size. One genus, Paracyclas, is uniformly one twenty-fifth the diameter normal to the species, and no larger individual has been observed. However, most of the lamellibranchs are only one fifth to one third the normal dimensions, and have thus for some unknown reason resisted the unfavorable environment better than the other groups. Their larvae are free swimming, and the adult moves about in a limited way, but they seem to have been brought up in the iron water. There are however no unusually large individuals or any which really approximate the size of normal adults in the Hamilton fauna. The lamellibranchs as a group are in a phylembryonic stage of development. It seems to be true in general that primitive members of a group have greater vitality in resisting unfavorable circumstances, and it may be that these forms are to be considered as primitive or ancestral. The gastropods and cephalopods possess, during their whole life, greater locomotive ability. Here there is a great variation in the size of the individuals of each species. Sometimes a form is one twenty-fifth the diameter of the ances-

tral species; sometimes one fifth, and occasionally one half as large. This is due, I believe, to greater freedom of motion. Some individuals of these two groups are born and grow to maturity in this iron water. These are greatly dwarfed. Others come into the iron water later in life, and are less modified. Thus one species comes to be represented by various sizes of individuals. This variation in size is specially marked among the cephalopods. The trilobites are scarce, only two fragments being found and these together. They are not particularly modified, though small for an adult. The water seems to have been hostile to this class of animals. Ostracods however are not scarce, and are not particularly dwarfed. Corals are wholly wanting.

As to the effects other than dwarfing, the brachiopods, having a well developed ornamentation, are best adapted to show such modification. The spirifers, with their rounded cardinal extremities, their short hinge line, few and simple plications, resemble adult Prehamilton far more than Hamilton forms. In these characters also the pyrite specimens resemble young or embryonic conditions. The goniatites, representatives of the genus Tornoceras, have an open umbilicus and a simpler suture line than their immediate Hamilton ancestors. In these respects they correspond to young Hamilton Tornocerata and represent a condition of arrested development. The shells of Tropidoleptus from the pyrite are higher than wide, and with acute cardinal extremities, like young forms of T. carinatus, and again express an arrested condition. Several pyrite species find the correlative expression of their characters among adult forms antedating the Hamilton fauna. In other words, they resemble ancestral forms; and, inasmuch as the ancestral line of development closely parallels the development of the individual, one finds the forms with the appearance of youth, though adults in development. They are not forms arrested at any particular stage in their development; but all throughout their lives they have been retarded in growth; so that finally they have reached maturity, though with the bodies of youth. These full grown pygmies, when compared with the umbo of the ancestral Hamilton species, will find their correlate in one of the early stages of that normal

form. It is thus that the various species have been here determined. However, when the area of the umbo which corresponds to the development of the pyrite form has been determined, it is noticeable that the pyrite form is strikingly smaller than the normal species at a corresponding stage. All of these fossils then represent cases of arrested development, with the understanding that the arrest is at no given point but all through the development. The Brachiopoda show the greatest modification; perhaps because they are the most specialized class and offer less resistance to the environment. The Cephalopoda, specially the goniatites, show modification in the next degree. Where they are dwarfed, they return to distinctly younger and more primitive appearing types. The Lamellibranchiata and Gastropoda, while often much dwarfed, vary but little in form from their Hamilton ancestors. This may be because they are less specialized groups. Under the unfavorable circumstances here presented, dwarfing is not the unusual but the ordinary phenomenon.

In considering the descriptions of the various species in the pages to follow, one will observe the frequency with which pyrite forms resemble forms from the Marcellus shales. The Marcellus was another foul water sea; and this seems to represent a recurrence of conditions then existing. The pyrite sea is undoubtedly much more unfavorable to its animal life, but the modifications are in the same direction in enough cases to be noticeable, so that the question is raised, whether a variety of unfavorable conditions does not affect the forms in a similar manner. Herbst's[1] experiments point in that direction, and these faunas also seem to do so.

A table, showing the species constituting this fauna and their distribution, is appended.

Descriptions of species

BRACHIOPODA

Genus SPIRIFER Sowerby

Of all the fossils in this group, the spirifers are the most abundant, most modified and the most instructive. Though found in so close association with a Hamilton fauna, not one

[1] *Loc. cit.*

has a Hamilton expression, but each form bears a close resemblance to an earlier representative of the genus. So striking is the resemblance, that one, shown the magnified drawings, might feel safe in pronouncing them to be from the fauna of the Onondaga limestone. Assigning these to their ancestral Hamilton species has not been an altogether simple task, but has been carried out by comparing the pyrite forms with the beaks of the Hamilton species. These eight species of Spirifer, illustrate better than any other group the results arising from a life in an unfavorable medium. They are reversion types of the most pronounced kind.

Spirifer fimbriatus Conrad, mut. simplicissimus nov.

Plate 3, fig. 1, 2

The shell is almost circular in outline a trifle higher than broad. It measures 1⅜ mm in breadth, 1½ mm in length and ½ mm in thickness. The ventral valve has a wide, moderately deep median sinus and no lateral ridges. The dorsal valve has a short, broad fold reaching about half way to the beak. The cast shows the impress of a low, broad septum. The valves are only moderately convex. This form is equivalent to the simplest form of spirifer development, and comparable to S. fimbriatus arrested in its earliest stage. It is not the young of some other of the occurring species, as it is larger than S. fimbriatus mut. pygmaeus, and far simpler than any other species of its size. That S. fimbriatus should develop two mutations is not remarkable, considering the variation the species shows under normal circumstances.

Localities. Canandaigua lake, Livonia salt shaft and Moscow, in abundance. Total 52 specimens.

Spirifer fimbriatus Conrad, mut. pygmaeus nov.

Plate 2, fig. 8, 9

The shell is almost circular in outline, being a trifle broader than high. An average adult measures 1¼ mm broad, 1 mm long and ½ mm in thickness. The ventral valve has a wide sinus starting at the beak, and two low, wide folds on either side reaching about half way to the beak. The beak is small and

acute. The dorsal valve has a short median fold and two lateral folds, none of which reaches more than half way to the beak. The septal impression is long and rather broad. Such a form resembles the S. raricosta Hall (Onondaga), but it is not so gibbous, nor are the folds so strong. It is a simplification of S. fimbriatus, and about one twenty-fifth as large. The dwarfing clearly began long before any shell was formed; for a normal S. fimbriatus would not show a trace of a fold on a shell 1 mm in diameter.

Localities. Canandaigua lake, Livonia salt shaft and Moscow, in abundance. Total 52 specimens.

Spirifer mucronatus Conrad, mut. hecate Clarke

Plate 3, fig. 13–15

Leiorhynchus ? hecate Clarke. U. S. Geol. Sur. Bul. 16. 1885. p. 31

This form is almost circular in outline, and not gibbous. It measures 1½ mm in hight, 1½ mm in breadth, and ⅞ mm in thickness. The ventral valve has a deep median sinus, and on either side five ridges, which reach about two thirds of the way to the beak. The median fold of the dorsal valve reaches a trifle over halfway to the beak, as do also the five lateral folds on each side. Near the blunt beak, the septum is deeply impressed. Thence a shallow groove runs along the middle of the median fold to the margin. The beaks are close, the ventral one overhanging the dorsal. Such a form suggests S. gregarius (Onondaga) in its younger forms. The resemblance to the adult S. mucronatus is not striking, but the groove in the fold of the dorsal shell, the low area, and the similarity to the umbo of S. mucronatus, indicate that this mutation is a modification of the above species.

Localities. This is the commonest of all the occurring forms and is found at Canandaigua lake, Livonia salt shaft and Moscow. Total specimens 116.

Spirifer medialis Hall, mut. pygmaeus nov.

Plate 3, fig. 9, 10

This form is broadly oval in outline, a trifle broader than high. It measures 2½ mm in width, 2⅛ mm in hight and 1½

mm in thickness. The ventral valve has a wide sinus flanked by six plications on each side, the innermost on either side being wider than the others. The dorsal valve has a broad, low fold with five ridges on each side running about two thirds of the way to the beak. There is also the beginning of a sixth ridge forming next to the median fold. The beaks are blunt and not prominent; area low. The form is suggestive of S. grieri Hall (Onondaga). It approximates closely to the beak of S. medialis, except in being much smaller than a normal S. medialis of that degree of development.

Localities. Abundant at Canandaigua lake, common at Livonia salt shaft and rare in the Moscow localties. Total specimens 35.

Spirifer tullius Hall, mut. belphegor Clarke

Plate 3, fig. 3, 4

Spirifera belphegor Clarke. U. S. Geol. Sur. Bul. 16. 1885. p. 30

This form is nearly round in outline, about as broad as high, with rounded extremities and a very high area. It measures 4 mm in breadth, 4 mm in hight and 3 mm in thickness. The extremely gibbous ventral valve has a narrow median sinus, flanked on either side by six ridges, which reach nearly to the beak. The beak of this valve is acute and prominent. The dorsal valve is less convex; beak low and not prominent; the median fold is low and flanked by six ridges on each side. The area is triangular and high. This corresponds to a young shell of S. tullius.

Localities. Rare at Canandaigua lake and near the Delaware, Lackawanna and Western Railroad at Moscow. Total specimens 3.

Spirifer granulosus Conrad, mut. pluto Clarke

Plate 3, fig. 7, 8

Spirifera pluto Clarke. U. S. Geol. Sur. Bul. 16. 1885. p. 31

This is a large, broadly oval form, with rounded extremities. It measures 4 mm in breadth, 2½ mm in hight and nearly 2 mm in thickness. Both valves are equally convex. The ventral shell has a broad obtuse beak; the median sinus wide and deep, flanked by eight broad, low ridges, each running three fourths

of the way to the beak. The dorsal valve has a low fold in the middle with eight ribs on each side. The median fold is grooved down the middle from near the beak. The resemblance of this mutation to the normal S. granulosus is striking, specially in the presence of the groove in the median fold, which in old individuals of the normal type dies out toward the margin.

Localities. Abundant at Canandaigua lake, Livonia salt shaft and all the Moscow localities. Total specimens 55.

Spirifer marcyi Hall, mut. pygmaeus nov.

Plate 3, fig. 5, 6

This is a large, broadly oval form, with rounded cardinal extremities. It measures 4 mm in width and 2 mm in hight. The hinge line is curved and reaches nearly to the extremities. The dorsal valve has a broad low median fold, reaching two thirds of the way to the beak. The six ribs on either side are rounded and wider than the intervening furrows.

Locality. A single specimen from the Livonia salt shaft.

Genus CYRTINA Davidson

Cyrtina hamiltonensis Hall, mut. pygmaea nov.

Plate 3, fig. 16

The single specimen of this shell observed is a dorsal valve, 3 mm broad and 1⅝ mm in length. The median fold is broad and moderately high, with three wide folds on either side of it. The surface is highly punctate. The shell is in all respects an immature phase of the Hamilton species to which it is referred.

Locality. Canandaigua lake.

Genus NUCLEOSPIRA Hall

Nucleospira concinna Hall, mut. pygmaea nov.

Plate 1, fig. 4; plate 2, fig. 5

This form is almost circular in outline, the valves slightly and equally convex, beaks small and incurved. The size is 1 mm in length, 1⅛ mm in breadth, and ½ mm in thickness. The valves are internal casts, but indicate a smooth surface. The ventral valve is unmarked; the dorsal has a slight depression

on the umbo. In one or two cases, traces of four muscular impressions are seen on the dorsal cast. The specimens are very perfect and probably more abundant than appears, as they are so easily overlooked on account of their small size. They are exact diminutives of the N. concinna, resembling it in every respect except size, adults in the pyrite being of about one fifteenth the normal diameter.

Localities. At the Livonia salt shaft, at Greigsville and at Moscow near the Delaware, Lackawanna and Western Railroad. Total specimens 10.

Genus AMBOCOELIA Hall

Ambocoelia umbonata Conrad, mut. pygmaea nov.

Plate 2, fig. 13–15

This is nearly circular in outline, the hinge line being very short, not over half the width of the shell; the cardinal extremities are broadly rounded. An average specimen measures 1½ mm in length, 1½ mm in breadth and ¾ to 1 mm in thickness. The gibbosity varies greatly. The ventral valve is strongly convex, with an elevated umbo, and a wide sinus from the beak to the margin. This last is bounded by rounded ridges. The small beak is incurved; the area is high, with a large pedicle opening. The dorsal valve is nearly flat, the beak only slightly raised, and just a trace of a low, wide ridge near the margin corresponding to the sinus on the ventral valve. The mutation resembles A. umbonata in most points, but differs in that the sinus of the ventral valve is shallower and broader in the presence of the fold on the dorsal valve, and in being one tenth its diameter. In diameter the specimens are remarkably uniform, but in thickness there is considerable variation.

Localities. This form is extremely abundant at Canandaigua lake and the Livonia salt shaft, and appears scatteringly in the Moscow localities. Total specimens 93.

Ambocoelia umbonata Conrad, mut. pluto nov.

Plate 2, fig. 16–18

A second Ambocoelia, somewhat larger than the foregoing, represents a phase corresponding to the A umbonata var. gregaria, but is of earlier occurrence and is dwarf. This is 3½ mm in width, 3⅛ mm in hight and 1⅛ in thickness. It

is characterized by a broad furrow on the ventral valve, and a shallow furrow on the dorsal, a combination which causes a notch in the margin. The beaks are broader and blunter than those of the foregoing. The cardinal extremities are almost angular. This is a very distinct type which seems to have been derived from A. umbonata.

Locality. Found only at Canandaigua lake. Total specimens 2.

Genus TROPIDOLEPTUS Hall

Tropidoleptus carinatus Conrad, mut. **pygmaeus** nov.

Plate 3, fig. 12

The outline of this form is truncated elongate oval. The hinge line slopes a trifle to the acute cardinal extremities. A typical shell measures $1\frac{7}{8}$ mm in breadth, 2 mm in length. The surface is covered by 13 radiating plications, of which the middle one does not reach more than halfway to the beak. The ribs are scarcely as wide as the intervening furrows. This mutation differs from the typical adult T. carinatus as follows: the shell is higher than wide; there are fewer plications; the ridges are not as wide as the furrows; the cardinal extremities are rounded; and the diameter is one fifteenth as great. In all these respects the pyrite form in a striking manner resembles a young T. carinatus. Its only variation from the young phase is in the median ridge not reaching the beak.

Locality. The specimens occur as ventral valves at Canandaigua lake. Total specimens 8.

Genus STROPHALOSIA King

Strophalosia truncata Hall, mut. **pygmaea** nov.

Plate 2, fig. 10, 12

Suboval shells, the hinge line sloping to either cardinal extremity, the margin being a broad, even curve. The cardinal extremities are angular. A typical specimen measures $2\frac{1}{2}$ mm in width and $1\frac{2}{3}$ mm in hight. The ventral valve is strongly convex, and shows a large scar of attachment on the umbo, in the figured specimen $\frac{5}{8}$ mm in diameter. The bases of spines are scattered over the surface with no real regularity, but there is an average of five in a concentric row. Compared with the

typical S. truncata, this pyrite form has about one third the diameter; is much more broadly truncated and is wider.

Localities. At Canandaigua lake and the Livonia salt shaft. Total specimens 14.

Genus PRODUCTELLA Hall

Productella spinulicosta Hall, mut. pygmaea nov.

Plate 2, fig. 11

Only one specimen of this has come to light from Canandaigua lake. It is like a P. spinulicosta but dwarfed. There is no truncation. Size is 4 mm wide by 4 mm high. The bases of several spines are impressed on the cast. Several concentric wrinkles are present, starting from the hinge line and dying out on the umbonal surface.

Genus TRIGERIA Bayle

Trigeria lepida Hall, mut. pygmaea nov.

Plate 3, fig. 11

This species is ovoid in outline, widest a little below the middle, and narrow near the beak. The size is $1\frac{1}{2}$ mm in hight and $1\frac{3}{8}$ mm in width. The beak is acute and prominent. The surface is covered by 12 narrow, prominent, radiating ridges; the intervening furrows being a little wider than the ridges.

Locality. Canandaigua lake and the Livonia salt shaft. Total specimens 8.

CRINOIDEA

Genus PENTREMITES Say

Pentremites leda Hall

Plate 1, fig. 1

A single specimen was found at Canandaigua lake, a calyx in fair condition. This is 6 mm high and 3 mm wide; i. e. about one third natural size. The pyrite form resembles the normal P. leda except that the ambulacra do not extend so far toward the base, and the base is more abruptly truncated.

There are also scattered through all the localities a considerable number of sections of the stems of two or three genera of crinoids, indicating that some of these creatures at least could live in this impure sea.

LAMELLIBRANCHIATA

Genus NUCULA Lamarck

Nucula lirata Conrad, mut. pygmaea nov.

Plate 1, fig. 14, 15

The form is triangular ovate, rounded more abruptly in front than behind. The beaks are near the front, and the valves gibbous. The length is about one fourth greater than the hight. The individual figured measures 2 mm in length, 1⅜ mm in hight and 1 mm in thickness. The pyrite form differs from the ancestral in the beaks being situated nearer the front, and in less gibbosity. Otherwise the resemblance is close, except that the dwarf is about one tenth the size of a normal N. lirata.

Localities. At the Livonia salt shaft and Greigsville. Total specimens 5.

Nucula corbuliformis Hall, mut. pygmaea nov.

Plate 1, fig. 10, 11

This form is an almost exact miniature of the normal N. corbuliformis. The specimens are internal casts showing the impress of the teeth, pallial line, adductor muscles, and the small muscles in the umbonal region. A specimen measures 10 mm in length, 7½ mm in hight and 5 mm in thickness; this being about one half the normal size.

Localities. At Canandaigua lake and at Livonia.

Nucula varicosa Hall, mut. pygmaea nov.

Plate 2, fig. 3, 4

The form is triangular ovate in outline, the anterior end being abruptly rounded, the posterior almost truncate. The beaks are nearly at the anterior end and approach each other closely. The valves are strongly gibbous, their surface showing slight wrinkles, apparently indicating varices on the exterior of the shell. The teeth have left no impress on the cast. The type is 2¼ mm in length, $1^2/_3$ mm in length and 1½ mm in thickness. They approximate N. varicosa closely except in size, being about one sixth the diameter.

Localities. Moscow, near the Delaware, Lackawanna and Western Railroad and on Little Beard's creek. Total specimens 2.

Genus NUCULITES Conrad

Nuculites triqueter Conrad, mut. **pygmaeus** nov.

Plate 1, fig. 16, 17

This species has a subtriangular outline, the length one fourth to one third greater than the hight. The valves are strongly and equally gibbous; umbones prominent; beaks strong and incurved. The clavicular septum is deeply impressed. A typical specimen measures $2\frac{1}{2}$ mm in length, $1\frac{3}{4}$ mm in hight and $1\frac{1}{2}$ mm in thickness.

Localities. The form is abundant, occurring at Canandaigua lake, Livonia salt shaft, Greigsville, at Moscow near the Delaware, Lackawanna and Western Railroad and Little Beard's creek. Total specimens 7.

Nuculites oblongatus Conrad, mut. **pygmaeus** nov.

Plate 1, fig. 7

A single specimen from Moscow is in all respects except size, like the N. o b l o n g a t u s. It seems to be an adult, but measures only 5 mm in length and 2 mm in hight.

Genus LEDA Schumacher

Leda rostellata Conrad, mut. **pygmaea** nov.

Plate 1, fig. 5, 6

The outline of this little, neat shell is falciform, the anterior end being abruptly rounded, lower margin long and regularly curved and the posterior end abruptly rounded. The hinge line is concave. The anteriorly situated beaks are large and incurved. The smaller of the two specimens shows considerable gibbosity in the umbonal region, and thence the shells taper toward the rear. The larger of two specimens measures $2\frac{1}{8}$ mm in length and 1 mm in hight, which is about one fourth the size of the ancestral form.

Localities. Canandaigua lake and Greigsville.

Genus PALAEONEILO Hall

Palaeoneilo plana Hall, mut. **pygmaea** nov.

Plate 1, fig. 8, 9

The outline of this species is subtriangular, the length about one fourth greater than the hight. The valves are moderately

convex; beaks on the anterior third and incurved. An average sized specimen measures 7 mm in length, 4½ mm in hight and 3 mm in thickness. These pyrite specimens differ from the typical P. plana in being somewhat shorter, in which they resemble young forms.

Localities. Fairly common at all the localities examined: i. e. Canadaigua lake, Livonia, Moscow and Greigsville. Total specimens 16.

Palaeoneilo constricta Conrad, mut. pygmaea nov.

Plate 1, fig. 12, 13

This form is subovate in outline, the length being about one half greater than the hight. The beaks are well to the anterior, and the valves moderately convex. Several concentric lines of growth are imprinted on the cast. The main and distinctive feature is a depression which runs from the beak to the rear margin of the shell.

Localities. Greigsville and Little Beard's creek, Moscow. Total specimens 3.

Genus PARACYCLAS Hall

Paracyclas lirata Conrad, mut. pygmaea nov.

Plate 1, fig. 2, 3

This neat little form is almost circular in outline, the anterior margin swelling out strongly, while to the rear the slope from the beak is very rapid. The beaks are centrally situated and directed to the front. They are small and incurved. The surfaces of the casts are perfectly smooth. A typical specimen measures 1⅛ mm in length, 1 mm in hight and ½ mm in thickness. As compared with the normal P. lirata, it has about one twentieth the diameter, shows no sign of ornamentation, looking like a young form. However, it occurs in great abundance presenting a remarkable uniformity of size and appearance.

Localities. It is the most abundant fossil at Canandaigua lake and the Livonia salt shaft and occurs also, though less abundant, at Greigsville. Total specimens 110.

Genus GRAMMYSIA DeVerneuil

Grammysia constricta Hall, mut. pygmaea nov.

Plate 2, fig. 1, 2

This little form has the shape of a truncated ovoid, the beak being at the anterior end. The hinge line is straight and two

thirds as long as the shell, the margin is evenly curved, rounding abruptly at the rear. From the beak a narrow furrow extends to the middle of the margin, making a constriction in the margin. The specimen measures 1½ mm long by 2-3 mm high and 4-5 mm in thickness. Its appearance is that of a young Grammysia, but it is much more developed than any such shell at that size.

Locality. Greigsville. 1 specimen.

Genus BUCHIOLA Barrande

Buchiola retrostriata v. Buch, mut. pygmaea nov.

Plate 2, fig. 7

In outline and general form this specimen resembles the species cited. However, the nodes are more rounded and more abundant than in that species. There are eight radiating ridges from the anteriorly placed beak. The central one of these has on it five low knobs, the others fewer. The shell measures 3 mm in length and 2½ mm in hight.

Locality. Little Beard's creek, Moscow. 1 specimen.

Genus CONOCARDIUM Bronn

Conocardium eboraceum Hall, mut. pygmaeum nov.

Plate 2, fig. 6

This imperfect single specimen from near the Delaware, Lackawanna and Western Railroad, Moscow, retains only enough to enable one to ascertain that it belongs to this species. For the pyrite, it is a large form, though not one fourth as large as the ancestral form.

GASTROPODA

Genus DIAPHOROSTOMA Fischer

Diaphorostoma lineatum Conrad, mut. belial Clarke

Plate 4, fig. 9

Platystoma belial Clarke. U. S. Geol. Sur. Bul. 16. 1885. p. 30

Like the typical P. lineata, the apex of the dwarf forms is not complete, but two and one half to three whorls are preserved in each case. The spire is low; whorls ventricose, specially the last one; aperture orbicular. There is considerable variability in the hight of the spire and the ventricosity of the last whorl; but all variations seem to grade into each other,

and the ancestral form is also extremely variable. There is great variability in the size of the individuals, some being ¾ mm in diameter, others as much as 10 mm; but all have the characteristic form. It occurs in moderate abundance in all the localities. Canandaigua lake, Livonia salt shaft, Greigsville and Moscow. Total specimens 28.

Genus MACROCHILINA Bayle

Macrochilina hebe Hall, mut. pygmaea nov.

Plate 4, fig. 4

The form is conical, about twice as high as wide. The specimen illustrated has four and one half complete whorls, the top being lost. The whorls are ventricose and the form slender. It measures as it stands 1½ mm in hight and 1 mm in diameter. This resembles the slenderer forms as they occur in the shale There are two specimens of this species, from near the Delaware, Lackawanna and Western Railroad at Moscow. They are one fifteenth normal size.

Macrochilina hamiltoniae Hall, mut. pygmaea Clarke

Plate 4, fig. 1

This species presents a shorter cone, the hight being about half again as great as the diameter. The spire is short, having but three whorls, the last whorl being ventricose and making about three fourths of the full hight of the shell. The aperture is oval, higher than broad, acute above and obtuse below. The mutation is an almost exact miniature of the ancestral M. primaevus from the Schoharie grit. It measures 1¼ mm in hight and ¾ mm in diameter. It occurs at Canandaigua lake and the Livonia salt shaft. Total specimens 8.

Genus PLEUROTOMARIA Defrance

Pleurotomaria capillaria Conrad, mut. pygmaea nov.

Plate 4, fig. 6

This species is represented by several fragmentary specimens. It is a low cone, the whorls being ventricose and rounded. On the upper part of each whorl are three to four revolving grooves, separated by intervening carinae. The hight of an average shell is 5 mm, while the thickness is the

same. The mouth of the shell is round, the hight and breadth being equal. This mutation is but moderately dwarfed and very little modified from the ancestral type. All the specimens came from Canandaigua lake and Livonia salt shaft. Total specimens 6.

Pleurotomaria itys Hall, mut. **pygmaea** nov.

Plate 4, fig. 5

These specimens are low cones about as high as broad, and consist of three whorls regularly expanding to the body whorl, which is ventricose. The aperture is about as high as broad and circular. The surface of the cast is smooth. The specimen used for illustration is a small one. It measures 3/8 mm in hight and 3/8 in diameter. No matter how dwarfed they may be, the specimens retain the ancestral proportions very closely. There is considerable variation in the size of the individuals, from the size of the one illustrated to one half normal size. They occur at Canandaigua lake and the Livonia salt shaft. Total specimens 8.

Beside the above, there are a good many fragments of Pleurotomaria-like shells, some large, some small.

Genus LOXONEMA Phillips

Loxonema delphicola Hall, mut. **moloch** Clarke

Plate 4, fig. 10

Loxonema moloch Clarke. U. S. Geol. Sur. Bul. 16. 1885. p. 30

This species is only moderately dwarfed, being one fourth to one third the normal size. It is a tall spire but never complete in the specimens found. The whorls are flattened and rise rapidly as if to make a very slender cone. It usually measures about 3 mm in diameter. The species is represented sparingly at the Livonia salt shaft and Moscow on Little Beard's creek. Total number of specimens 7.

Genus TENTACULITES Schlotheim

Tentaculites gracilistriatus Hall, mut. **asmodeus** Clarke

Plate 4, fig. 11

Orthoceras asmodeus Clarke. U. S. Geol. Sur. Bul. 16. 1885. p. 31

This tiny species has a needlelike form, tapering to a fine point. The upper surface is marked by regular undulations,

which, toward the point, die out and leave the shell smooth. The figured specimen is 1⅞ mm long and ¼ mm in diameter at the thickest part. The undulations only cover the upper half of the shell. The form is about one half as large as the T. gracilistriata, and does not vary materially from that in shape or ornamentation. It occurs abundantly at the Livonia salt shaft. Total specimens 5.

Tentaculites bellulus Hall(?), mut. stebos Clarke

Plate 5, fig. 8

Orthoceras stebos Clarke. U. S. Geol. Sur. Bul. 16. 1885. p. 29

This is a larger and rarer form than the preceding. It is characterized by its surface being covered by narrow ribs, at some distance from each other, the intervals being about three times as great as the width of a rib. The specimens are merely fragments but show the size to be about the same as the normal T. bellulus. It is found only at the Livonia salt shaft, and probably represents individuals which have drifted into the pyrite waters. Total specimens 2.

CEPHALOPODA

Genus ORTHOCERAS Breyn

Orthoceras subulatum Hall, mut. pygmaeum nov.

Plate 5, fig. 6, 7

To distinguish between O. subulatum and O. constrictum from the cast, and without the chamber of habitation, is impracticable; so what may represent two species is placed here under one head. The shells are smooth, with a circular cross section, and an apical angle of 6° to 8°. The siphuncle is central or nearly so. Each chamber is about one third as high as its diameter. Most of the specimens are from 1 to 2 mm in diameter, but not infrequently larger individuals, up to 6 mm in diameter, occur. There is nothing other than size to distinguish the pyrite forms from the normal type. The appearance of these sporadic large forms, as explained in the introductory paragraphs, seems to be due to their having drifted from nonaffected areas into the iron saturated waters. This species occurs quite abundantly in all the localities. It is usually small at Canandaigua lake and Livonia salt shaft. At

Greigsville it is rare, but at Moscow it is abundant, specially near the Delaware, Lackawanna and Western Railroad, where there is the greatest number of larger forms. Total specimens 29.

Orthoceras scintilla Hall (?), mut. mephisto Clarke

Plate 4, fig. 14

Orthoceras mephisto Clarke. U. S. Geol. Sur. Bul. 16. 1885. p. 29

This tiny form is smooth on the surface, it is extremely slender, circular in section and tapers very slowly, 3° being its apical angle. The siphuncle is central and rather small, not deeply impressed on the cast. The length of a chamber is about equal to the diameter. The pyrite form differs from its progenitor in being about one fifth to one fourth as large, and in the siphuncle being smaller in proportion. Otherwise the resemblance is striking, the great length of the chambers being the distinguishing feature. It measures $^1/_3$ of a mm in diameter, and is very uniform in size. It occurs at Canandaigua lake and Livonia salt shaft with fair abundance, and sparingly at Greigsville. Total specimens 25.

Orthoceras nuntium Hall

Plate 5, fig. 9

This species, characterized by its undulating surface, occurs at Canandaigua lake and Livonia, being scarcely dwarfed. It seems to occasionally have drifted into the foul iron waters, but not to have lived there; for not a single dwarf of the species came to light.

Genus BACTRITES Sandberger

Bactrites (sp.) mut. pygmaeus nov.

Plate 4, fig. 12, 13

A single specimen consisting of three chambers in a fine state of preservation was found. The surface is smooth. The section is circular. Siphuncle close to the side, septa strongly oblique, apical angle 5°. The form is very like the species described as Orthoceras aptum, from the Marcellus shales. It measures 2 mm in diameter and 4 mm in length. Found at Canandaigua lake.

Bactrites (sp.) mut. parvus nov.

Plate 5, fig. 4, 5

Two specimens, each about 2½ mm in diameter, occur. The surface is smooth, section circular, ventral side marked by a moderately strong carina, septa slightly oblique, siphuncle unknown. This suggests strongly Orthoceras marcellum. Two specimens, one from Canandaigua lake, the other from Livonia salt shaft.

Genus TORNOCERAS Hyatt

Tornoceras uniangulare Conrad

Plate 5, fig. 3

This species is the one from which the mutation to follow has been derived. The specimens found in the pyrite are from one fourth to one half the normal size, and appear like old individuals. The species is characterized by a depressed discoidal shell, closed umbilicus, smooth surface, thin septa, each with a prominent saddle on the inner side of the disk, a deep lateral lobe and a narrow, semielliptic ventral saddle. The pyrite specimens, though small, are similar to the normal type. They represent forms which have drifted into the pyrite-depositing waters. There are 6 specimens in all, from Canandaigua lake, Livonia salt shaft and Moscow near the Delaware, Lackawanna and Western Railroad.

Tornoceras uniangulare Conrad, mut. astarte Clarke

Plate 5, fig. 1, 2

Goniatites astarte Clarke. U. S. Geol. Sur. Bul. 16. 1885. p. 29

This form occurs with greater frequency than any other in the pyrite. It appears in three distinct forms. The first is a gibbous disk, whose thickness is to the diameter as 3 is to 7. The umbilicus is open and of moderate size. There are usually three whorls and no indication of the dwelling chamber. The section of a whorl is semielliptic, the inner side being deeply indented by the embraced inner whorl. The inner whorl reaches to about one half the hight of the surrounding one. In the younger whorls the indention is less. The outer shell is lacking, but on the cast are light swinging striae, indicating stronger striae on the outside of the shell. The septa are dis-

tinct and swing forward to make a wide, shallow lateral saddle, then back, making a shallow lobe, and forward again, making a narrow ventral saddle. The two ends of the suture line do not meet, as the siphuncle intervenes. This variety has the suture line of T. uniangulare, but differs in the open umbilicus. It is also thicker in proportions. These are points possessed by a young T. uniangulare; but at the stage when the normal young has such a form, it has a much simpler suture line. This variety occurs most abundantly in all localities.

A second variety is the more gibbous form, called by Clarke G. astarte. Its suture line has only a single lateral lobe and a shallow ventral saddle. There are usually two and one half whorls. The thickness is to the breadth as 1 is to 2. These seem to be young forms of the above.

The third variety is well marked off, in that it has a strong constriction on the outer whorl, a character which is seldom seen on the American Devonic Goniatites.

All these forms occur at Canandaigua lake, Livonia salt shaft, Greigsville and Moscow, both at Little Beard's creek and near the Delaware, Lackawanna and Western Railroad. Total number of specimens 131.

CRUSTACEA

Genus CRYPHAEUS Green

Cryphaeus boothi var. calliteles Green

Plate 5, fig. 15

Trilobite remains are extremely rare in the pyrite, two fragments representing all the individuals. The larger fragment includes a glabellum and the first body segments. This is a small individual, agreeing in every way with C. calliteles; showing even the nodes along the axial line of the body. The second fragment is an isolated eye of Dalmanites. They were found at Little Beard's creek near Moscow and appear to be parts of a stray trilobite which wandered into the pyrite area to die.

Inasmuch as the Ostracoda from the Hamilton have not been described, I have given those found specific names, as they are the representatives of an otherwise unknown fauna.

Genus BEYRICHIA McCoy

Beyrichia dagon Clarke

Plate 5, fig. 12–14

Beyrichia dagon Clarke. U. S. Geol. Sur. Bul. 16. 1885. p. 29

This form is broadly ovate in outline, widest toward the rear, the anterior being abruptly rounded. The valves are strongly gibbous, specially toward the rear. Just in front of the middle on either side a broad valley goes from top to bottom. In this there rises a moderate node extending about halfway from top to bottom, and as high as the shell outside the valley. The shells run very uniform in size, a typical one measuring $\frac{3}{5}$ mm in length, $\frac{1}{3}$ mm in hight and $\frac{3}{8}$ mm in thickness. This form is common at the Livonia salt shaft, and occurs sparingly at Canandaigua lake and Moscow.

Genus ENTOMIS Jones

Entomis prosephina nov.

Plate 5, fig. 10, 11

This is represented by a single but finely preserved specimen. The outline is broadly ovate, valves extremely gibbous, shell punctate. Near the front there are two concentric lines as for a beak. Just forward of the middle on each side is a deep sickle-shaped depression. The lower anterior end is drawn out and compressed into a plowlike, rounded projection. The measurements are, hight $\frac{7}{8}$ mmm, length $1\frac{1}{8}$ mm and thickness $\frac{7}{8}$ mm. The specimen is from Canandaigua lake.

Table of distribution

	Canandaigua lake	Livonia salt shaft	Little Beard's creek near Moscow N. Y.	Moscow near the D. L. & W. R. R.	2 miles N. of Moscow	Greigsville	Total
Spirifer fimbriatus, *mut.* simplicissimus *nov*	1	23	13	5	...	10	52
Spirifer fimbriatus, *mut.* pygmaeus *nov*	7	17	11	7	...	9	51
Spirifer mucronatus, *mut.* hecate *Clarke*	15	23	30	29	1	18	116
Spirifer medialis, *mut.* pygmaeus *nov*	7	12	12	1	...	3	35
Spirifer tullius, *mut.* belphegor *Clarke*	2	..	...	1	...	...	3
Spirifer granulosus, *mut.* pluto *Clarke*	10	8	19	6	4	8	55
Spirifer marcyi, *mut.* pygmaeus *nov*	...	1	...	...	...	...	1
Cyrtina hamiltonensis	1	...	..	...	...	...	1
Nucleospira concinna, *mut.* pygmaea *nov*	...	2	5	...	...	3	10
Ambocoelia umbonata, *mut.* pygmaea *nov*	35	27	6	7	2	19	96
Ambocoelia umbonata, *mut.* pluto *nov*	2	...	...	...	...	...	2
Tropidoleptus carinatus, *mut.* pygmaeus *nov*	8	...	...	...	...	...	8
Strophalosia truncata, *mut.* pygmaea *nov*	5	9	...	...	...	...	14
Productella spinulicosta, *mut.* pygmaea *nov*	1	...	...	...	...	...	1
Trigeria lepida, *mut.* pygmaea *nov*	7	1	...	...	...	...	8
Pentremites leda	1	...	...	...	...	...	1
Crinoid stems	3	6	4	3	...	7	23
Nucula lirata, *mut.* pygmaea *nov*	...	2	1	...	...	...	3
Nucula corbuliformis, *mut.* pygmaea *nov*	1	1	...	...	...	...	2
Nucula varicosa, *mut.* pygmaea *nov*	...	...	1	1	...	...	2
Nuculites triqueter, *mut.* pygmaeus *nov*	1	1	3	1	...	1	7
Nuculites oblongatus, *mut.* pygmaeus *nov*	...	...	1	...	...	...	1
Leda rostellata, *mut.* pygmaea *nov*	1	...	...	...	...	1	2
Palaeoneilo plana, *mut.* pygmaea *nov*	3	2	3	1	5	2	16
Palaeoneilo constricta, *mut.* pygmaea *nov*	...	...	...	1	...	2	3
Paracyclas lirata, *mut.* pygmaea *nov*	41	65	...	...	...	4	110
Grammysia constricta, *mut.* pygmaea *nov*	...	...	...	...	...	1	1
Buchiola retrostriata, *mut.* pygmaea *nov*	...	...	1	...	...	...	1
Conocardium eboraceum, *mut.* pygmaeum *nov*	...	...	...	1	...	...	1
Diaphorostoma lineatum, *mut.* belial *Clarke*	4	10	8	1	2	3	28
Macrochilina hebe, *mut.* pygmaeus *nov*	...	...	...	2	...	...	2
Macrochilina hamiltoniae, *mut.* pygmaeus *nov*	4	3	1	...	...	...	8
Pleurotomaria capillaria, *mut.* pygmaea *nov*	2	4	...	...	...	...	6
Pleurotomaria itys, *mut.* pygmaea *nov*	2	6	...	...	...	...	8
Pleurotomaria	8	18	7	8	...	9	50
Loxonema delphicola, *mut.* moloch *Clarke*	...	2	3	...	1	1	7
Tentaculites gracilistriatus, *mut.* asmodeus *Clarke*	...	5	...	...	...	...	5
Tentaculites bellulus,? *mut.* stebos *Clarke*	...	2	...	...	...	...	2
Tornoceras uniangulare	2	...	...	2	1	1	6
Tornoceras uniangulare, *mut.* astarte *Clarke*	26	42	18	11	1	22	120
Orthoceras subulatum, *mut.* pygmaeum *nov*	11	4	8	9	1	2	35
Orthoceras scintilla(?), *mut.* mephisto *Clarke*	3	18	1	...	...	3	25
Orthoceras nuntium	1	2	...	...	...	...	3
Bactrites (sp) *mut.* pygmaeus *nov*	1	...	...	...	...	...	1
Bactrites (sp)? *mut.* parvus *nov*	1	1	...	...	...	...	2
Cryphaeus boothi, *var.* calliteles	...	...	2	...	...	...	2
Entomis prosephina *nov*	1	...	...	...	...	...	1
Beyrichia dagon *Clarke*	2	12	1	...	...	1	16
48 species							
Total specimens	...	...	...	...	...	...	853

Summary

At the horizon of the Tully limestone, but where it has otherwise run out, there occurs a layer of pyrite which spreads over a considerable part of western New York. It is a more or less discontinuous deposit, appearing as lenses, each covering considerable area, but not over 1 foot in thickness. This pyrite contains a fauna of dwarfed forms, consisting of not less than 45 species. The sea is one whose waters were polluted with iron in solution, and by decaying vegetation. These two together have made an unfavorable environment, which has dwarfed the forms inhabiting it, till they are on an average only one fifteenth the size of the same species in the normal and preceding Hamilton fauna. The iron in the water as ferrous carbonate, was probably precipitated by the sulfuretted hydrogen ($FeOCO_2+H_2S=FeS+CO_2+H_2O$) and thus formed pyrite. This impure water acted on several generations of animals, but the succeeding generations are no more dwarfed than the first which was subjected to the peculiar surroundings. In addition to the dwarfing the fauna is strongly modified in form, the species appearing in some cases like those of faunas still earlier than the Hamilton, and like young in all cases. This is an instance of arrested development, in which the brachiopods show the most modification. The species have been described as mutations of the various Hamilton species, though the variation is greater than in many species, but the ancestry is evident, and determined by comparison with the young of the ancestral species.


SKETCH MAP OF
NEW YORK STATE
SHOWING DISTRIBUTION
of
MASTODON REMAINS
SCALE
0 10 20 30 40 80
LAKE ONTARIO
LAKE ERIE
VERMONT
MASS.
CONN.
NEW JERSEY
LONG ISLAND SOUND
ATLANTIC OCEAN
CLINTON
FRANKLIN
ST. LAWRENCE
ESSEX
JEFFERSON
LEWIS
HAMILTON
WARREN
WASHINGTON
OSWEGO
ONEIDA
HERKIMER
FULTON
SARATOGA
NIAGARA
ORLEANS
MONROE
WAYNE
ONONDAGA
GENESEE
MONTGOMERY
ONTARIO
MADISON
SCHENECTADY
RENSSELAER
ERIE
WYOMING
LIVINGSTON
YATES
SENECA
CAYUGA
CORTLAND
OTSEGO
SCHOHARIE
ALBANY
CHENANGO
SCHUYLER
TOMPKINS
GREENE
CHAUTAUQUA
CATTARAUGUS
ALLEGANY
STEUBEN
CHEMUNG
TIOGA
BROOME
DELAWARE
COLUMBIA
ULSTER
DUTCHESS
SULLIVAN
ORANGE
PUTNAM
WESTCHESTER
ROCKLAND
YORK
RICHMOND
KINGS
QUEENS
NASSAU
SUFFOLK

MASTODONS OF NEW YORK

A LIST OF DISCOVERIES OF THEIR REMAINS 1705-1902

COMPILED BY JOHN M. CLARKE

The effort has been made to render this list complete, though it is quite probable that finds have been made which have never been recorded, doubtless some which have not been recognized as mastodons. In most instances the bones have gone into public and private museums, but some that have left the State may also have failed of record.

We present a list of about 60 of these occurrences.

It is of interest in more than one particular. Forty years ago the plains of the West and Southwest swarmed with immense herds of the buffalo, whose bones left on the ground have gone as completely as have their bodies. The dry air and arid soil have reduced to dust millions of these skeletons. In the moist and cold climate of the postglacial East where the mastodon must have traversed New York in much the same abundance as the buffalo did the West, the watersoaked soil has preserved now and again a skeleton of this race. Not every Mastodon americanus ended his days in a peat bog.

It is to be noted that these occurrences, specially when considerable parts of the skeleton have been found, are in swamps and bogs of flood plains and beaches which, in the high water period succeeding the ice, were river bottoms. The fall of the water, with other conditions, reduced these bottoms to pools on which vegetation gradually encroached, but neither they themselves, nor their contents can be of very ancient date. We may not safely deny the presence of the mastodon here during the early period of high water, but we may conclude that he remained to a comparatively recent date, when the floods had begun their retreat to their present confines.

Worthy of notice also is the distribution of these skeletons. In two regions of the State they have proved specially numerous. Orange county leads as the home of mastodon remains, with a record of 24 skeletons. The lower Hudson valley counties, Sullivan, Orange, Ulster and Greene afford 34 records. The region covered by Monroe, Ontario, Genesee, Livingston, Orleans and Wyoming counties records 14 skeletons. These two regions were

the hunting grounds of the mastodon, possibly its breeding places. The series of swamps in the long Appalachian valleys of Orange and adjoining counties runs southward into New Jersey, and there the mastodon bones are also found with frequency. Strangely, throughout the belt of territory between the Delaware river on the east and eastern Tompkins county on the west (virtually the meridian of Cayuga lake), a distance of about 100 miles, and thence north and south across the State, no single instance is shown by the record, of the presence of these remains. This can not be due to the fact that swamps and pools have not existed over this region, but must be ascribed to the gregarious habit of the animals and to the fact that some inducement brought them together in the other regions; probably more favorable conditions for feeding and breeding. Western New York is a region of salt licks, but the central region is equally so, while the lower Hudson presents no such inducement.

I insert here a page (492) from an article by F. A. Lucas of the National Museum, on the Restoration of Extinct Animals, published in the annual report of the Smithsonian Institution for 1900 and by courtesy of the secretary a copy of Gleeson's drawing which accompanies Mr Lucas's paper.

The mastodon is an elephant, and his general appearance is indicated [in the accompanying drawing by J. M. Gleeson], but there are certain details some of which are purely deductive and some of which have fortunately been proved for us. The skeleton shows that, taking it as a whole, the mastodon and African elephant represent two extremes of elephantine structures, the latter being the highest or longest legged, the former being for its bulk the lowest, most massive species known, although low is a comparative term, for the animal attained a hight of 10 feet. Yet when the skull and teeth are considered, these two animals have decided points of resemblance. The skull of the African elephant is flatter than that of the Indian species; the skull of the mastodon is even more depressed, and, as this feature would have shown plainly in life, it should be borne in mind in making any restorations. Many mastodon tusks have been found, and thus we know that they were slightly heavier, more abruptly tapering than in the mammoth or Indian elephant, and that, while there was great variety in the curve, in the typical examples from eastern North America they described nearly a half circle. In supplying the mastodon with a trunk it is to be borne in mind that there is a striking difference between the trunks of the Asiatic

Plate 1

Mastodon americanus

and African elephants, that of the former wrinkling up when bent, as though it were equally elastic throughout, while that of the latter bends, as it were, in sections, suggesting the joints of a telescope. As the skull and teeth of the mastodon are simpler in structure than those of the Indian elephant, and in these particulars more like the corresponding parts of the African elephant, it is a fair inference that the trunk was similar and that it also lacked the fingerlike process of the Indian species. The northern mammoth was clad in hair and wool, and, as the mastodon ranged well to the north, it is fair to suppose that the more northern individuals were more or less completely clad in hair. And this supposition is substantiated by the discovery noted by Rembrant Peale of long, coarse, woolly hair, in one of the swamps of Ulster county, N. Y. Thus the restoration of the mastodon represents a proportionately lower, more heavily built elephant than those now living, with recurved tusks and jointed trunk, and clad in fairly long hair.

Suffolk county

1823 Riverhead

More than one half of lower jaw with teeth; found between tides, 4 miles east of Riverhead.

Rockland county

1817 (De Kay, Nat. Hist. N. Y.; Zool. 1842. pt 1, p. 103)

Orange county

1790-1800 Montgomery

Bones of the mastodon were found in 1790-91 and 1800 in the town of Montgomery about 12 miles from Newburg, Orange county. They were 10 feet below the surface, in a peat bog in marl. Several bones of the legs, some of the vertebrae, several ribs, and some of the bones of the head were obtained. . . "Eight similar skeletons have been discovered within eight or 10 miles of the neighboring country, and some of them were fifteen or twenty feet below the surface of the earth." (*S. Mitchell. Medical Repository, New York. 1801. 4:212*) All these specimens were discovered between 1790 and 1800. Some bones of these animals were found in 1782 3 miles south of Ward's bridge in Montgomery, Orange county; another locality 1 mile east of the above bridge; another 3 miles east; another 7 miles northeast; another 7 miles east; another 5 miles westwardly from the same bridge; and another 10 miles north of the same bridge in the town of Shawangunk. *Mather. Geol. First Dist. 1842. p. 232-33.*

With regard to some of these finds Eager, in *History of Orange County,* 1843, p. 73, gives the following particulars.

1782 Three miles south of the village of Montgomery, on the farm now owned by Mr Foster Smith, the bones were visited by Gen. Washington and other officers of the army when encamped at Newburg, 1782-83. The Rev. Robert Annan, who then owned the farm, made a publication at the time, describing the bones, locality, etc., which caused Mr Peale subsequently to visit this county.

1794 Found about 5 miles west of the village of Montgomery, just east of the residence of Archibald Cranford esq. and near the line of the Cochecton turnpike.

1800 They were found about 7 miles northeast from Montgomery on or near the farm of Dr George Graham.

THE PEALE SKELETONS

1801 1 First found in 1799; further excavated 1801 by Charles Wilson Peale "in the vicinity of Newburgh." The original bones "consisting of all the neck, most of the vertebrae of the back, and some of the tail; most of the ribs, in greater part broken; both scapulae; both humeri, with the radii and ulnae; one femur; a tibia of one leg and a fibula of the other; some large fragments of the head; many of the fore and hind feet bones; the pelvis somewhat broken, and a large fragment, 5 feet long, of one tusk about midway." He was therefore in want of the back and tail bones, some of the ribs, the under jaw, one whole tusk and part of the other, the breast bone, one thigh, and a tibia and fibula and many of the feet bones. Subsequent excavations added little. *Rembrant Peale. The Mammoth. 1803*

1801 2 "Eleven miles distant from the former" (no. 1) Orange county. Found first in 1793. Excavated by C. W. Peale. 1801. Scattered parts only.

1801 3 Found in 1798 on farm of Peter Millspaw "crossing the Walkill at the falls." "Twenty miles west of the Hudson." Excavated by C. W. Peale. Many of the large bones found, including under jaw.

1803 Montgomery

"Found 1 mile east of Montgomery on the farm now owned by Dr Charles Fowler." *Eager. Hist. Orange County. 1848. p. 73*

Eager states that these were the bones dug out by Mr Peale in 1805-6, and that he as a boy witnessed the excavation. R. Peale's book on the "Mammoth," in which he gives the account of his father's excavations, was printed in 1802. This of 1805 may have been a later undertaking.

1817 Chester

Number of bones not known.

1838 Montgomery

A tooth was found by Mr Daniel Embler, of Newburg, on or near the farm of Samuel Dixon esq., of that town. *Eager. Hist. Orange County. 1848. p. 73*

1843 Orange county

Bones of this animal are now (Sep. 16, 1843) being disinterred from the marl underlying peat in a marsh in Orange county. *Mather. Geol. First Dist. Addenda. 1843. p. 636*

1844 Scotchtown ("The Shawangunk Head")

A fine head with a few other bones. "The strata covering it were 1st gravel, 2d marl, 3d peat." *Warren*

1845 The Warren mastodon

This, the most complete and one of the largest skeletons yet obtained, was found in the immediate vicinity of Newburg on the farm of N. Brewster. The skeleton lay with most of its parts together, on stony clay, overlain by shell marl, moss, peat and water. It was purchased by Dr John C. Warren and removed to Boston, its present location. Nothing is wanting except a part of the sternum and a few caudal vertebae and small foot bones.

1845 Hamptonburg

Found 12 miles southeast of Montgomery, on farm of Jesse C. Cleve. *Eager. Hist. Orange County. 1848. p. 73*

1874 Otisville

Found on sand and clay beneath a deep bed of muck on farm of Alexander Mitchell. Purchased by Prof. O. C. March and now in Peabody Museum, New Haven.

Skeleton complete with exception of hind legs and tusks. *C. E. Beecher*

1879 Salisbury Mills

Nine miles southwest of Newburg. This skeleton is now mounted in the American Museum of Natural History. Professor Whitfield sends the following memorandum concerning "it":

The pelvis and three ribs are from Hangman's creek in Oregon. Tusks are from Hoopston, Ill. A few of the foot bones are restored. All the rest is from the one individual and place except the caudal appendage, the extension of which was modeled from Jumbo's tail.

1899 Newburg

A nearly entire skeleton found on the farm of F. W. Schaeffer, 3 miles west of Newburg, under muck and shell marl lying on a stony pavement. The skeleton lacked 20 vertebrae, one scapula and all of legs and feet excepting about 20 phalanges. It was restored and mounted and is now in the museum of the Brooklyn Institute.

1901 Monroe

Found, for the most part, about 1888, on land of Martin Konnight. The bones lay beneath 3 feet of clayey muck at the bottom of a pond 3 to 10 feet deep. Further excavations were carried on in 1901 by J. M. Clarke. The bones found consist of rather more than one half the entire skeleton: two tusks, 8 to 9 feet in length, the two tusks of the lower jaw, scapula, tibia, femur, ribs, vertebrae, etc. They are in possession of the New York State Museum.

1901 Arden

Tusk and a few other bones.

1902 Balmville

Found on George Gordon estate. Bones lay at depths of from 2 to 8 feet below the surface, some in the muck and some in marl below. Under the marl is a boulder pavement. There have been found (Oct. 30) cranium and lower jaw, one tusk (7 feet), 18 ribs, 14 vertebrae, some foot bones.

Sullivan county

1827 Between Red Bridge and Wurtsboro

The fossil remains of a *Mastodon giganteum* were discovered last autumn by workmen while digging

the Delaware and Hudson canal. A considerable portion of the skeleton has arrived in this city, and I have enjoyed an opportunity of examining it. The bones which I saw are in good preservation and seem to justify the wishes of the proprietors to set up the entire skeleton. The teeth are in perfect order. One of the tusks has arrived; it is a beautiful and perfect specimen, 9 feet long. *Jeremiah Van Rensselaer. Am. Jour. Sci. 1828. 14:33*

Ulster county

1859? Ellenville

Tusk, parts of skull and several other bones; in State Museum, which also has a smaller tusk marked as from the same locality.

Greene county

1705 New Baltimore

See Claverack, Columbia co.

Date? Greenville

(*Hall. Geol. Fourth Dist. 1843. p. 367.*)

1840 Freehold

Atlas (American Museum of Natural History).

Dutchess county

1854 Poughkeepsie

A skeleton of a mastodon has been recently discovered buried in a marsh about 2 miles from Poughkeepsie, New York. Its state of perfection is not known, as it is yet but partly exhumed. This is the second specimen obtained from the vicinity of this city. *Am. Jour. Sci. ser. 2. 1854. 18:447.*

This seems to me to be the same find recently described to me by Prof. W. B. Dwight who writes: "The chief find of mastodon bones here occurred 40 or perhaps 45 years ago in a small circular pond (in an unusually dry season I believe) on what is called the Creek road, and from 2 to 3 miles northeasterly from the city. The bones were of large size and were, I think, put into the hands of a library association called the Lyceum. What became of them nobody knows."

A vertebra from Poughkeepsie is in the State Museum.

Columbia county

1705 Claverack

This is about the date of discovery of the first known bones of the American mastodon. They were found near the village of Claverack, and the first account of them is given in a letter from Governor Dudley to the Rev. Cotton Mather D.D., dated Roxbury, July 10, 1706.[1]

In this he states that a tooth with some other bones were brought to him by two "honest" Dutchmen of Albany who said that they were "taken up under the Bank of the Hudson's River some miles below the city of Albany about fifty leagues from the sea." Governor Dudley adds that a tooth of the same character was, the year before, "presented to My Lord Cornbury." Lord Cornbury addressed to the secretary of the Royal Society, a letter dated New York 1713.[2] This is as follows:

I did, by the Virginia fleet, send you a Tooth, which, on the outside of the box, was called the tooth of a Giant, and I desired it might be given to Gresham College: I now send you some of his bones, and I am able to give you this account. The tooth I sent was found near the side of Hudson's river, rolled down from a high bank by a Dutch country-fellow, about twenty miles on this side of Albany, and sold to one Van Bruggen for a gill of rum. Van Bruggen being a member of the Assembly, and coming down to New York to the Assembly, brought the tooth with him, and shew'd it to several people here. I was told of it, and sent for it to see, and ask'd if he would dispose of it; he said it was worth nothing, but if I had a mind to it, 'twas at my service. Thus I came by it. Some said 'twas the tooth of a human creature; others, of some beast or fish; but nobody could tell what beast or fish had such a tooth. I was of opinion it was the tooth of a giant, which gave me the curiosity to enquire farther. One Mr Abeel, Recorder of Albany, was then in town, so I directed him to send some person to dig near the place where the tooth was found; which he did, and that you may see the account he gives me of it, I send you the original letter he sent me; you must allow for the bad

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[1] In Eager's History of Orange County; also quoted in Warren's Mastodon giganteus, p. 198.

[2] *See* C. R. Weld. History of the Royal Society. 1848. 1:421.

English. I desire these bones may be sent to the tooth, if you think fit. When I go up to Albany next, I intend to go to the place myself, to see if I can discover any thing more concerning the monstrous creature, for so I think I may call it.

Mr Abeel's letter runs thus:

According to your Excellency's order, I sent to Klaverak to make a further discovery about the bones of that creature, where the great tooth of it was found. They have dug on the top of the bank where the tooth was roll'd down from, and they found, fifteen feet underground, the bones of a corpse that was thirty feet long, but was almost all decayed; so soon as they handled them they broke in pieces; they took up some of the firm pieces, and sent them to me, and I have ordered them to be delivered to your Excellency.

Dr Mather also addressed under date of Boston, Nov. 17, 1712, a communication to Dr Woodward on the same subject, and this was published in the *Philosophical Transactions of the Royal Society* in 1714 [29:62]; and he also, as does the publication just quoted, refers to two distinct localities, one, "Claverack, about 30 miles on this side of Albany, New England," the other, evidently that mentioned by Lord Cornbury, "as found 20 miles south of Albany on the bank of the river," thus perhaps in the town of New Baltimore.

Dr Mather inclines to the opinion of there having been, in the antediluvian world, giants, or men of very large and prodigious stature, by the bones and teeth of some large animals . . . which he judges to be human; particularly a tooth which was a very large grinder, weighing 4 pounds and 3 quarters, with a bone, supposed to be a thigh bone, 17 feet long.

Albany county

1835? Coeymans

Found on the farm of Mr Shear 4 or 5 miles west of the Hudson. *Mather. Geol. First Dist. 1842. p. 44*

1866 Cohoes

The conditions under which this skeleton was found are unique. The greater part of it lay buried in the

debris filling a great pothole in the Hudson river shales, exposed in digging the foundations for the Harmony (Mastodon) mills in Cohoes. This pothole was actually a double one, formed by breaking down the wall between two adjoining, and was the largest of many that lay above the flood plain of the present Mohawk river. Their origin was ascribed by Hall to the action of water flowing through crevasses in the glacial sheet. A portion of the skeleton referred to was found in a smaller pothole 60 feet away and 20 feet higher than the larger. After several thousand loads of muck with branches of trees had been removed, the first bones were found. Continued excavation exposed the major part of the skeleton, lying on a bed of clay, broken slate, gravel and waterworn pebbles and covered with vegetable soil. The gravel beneath was penetrated by rods to a depth of 10 feet without striking rock.

Of the bones most of the larger were obtained, but many small ones were lost. Numerically reckoned, 84 bones were found, 189 were not.

Professor Hall regarded this skeleton as derived from a carcass which had been frozen into the glacial ice and caught in these subglacial potholes; but, when we reckon the chances of a carcass being thus picked up by the ice sheet and of this chance carcass being caught in a pothole, we imply, either, that englacial carcasses were not infrequent or that the rock surfaces traversed by the ice were dotted with potholes. The latter proposition is not generally true, the former, judged by our knowledge of the mastodon, not probable. This carcass more probably belongs to the period of the swamps by which this pothole area was covered after the fall of the postglacial waters.

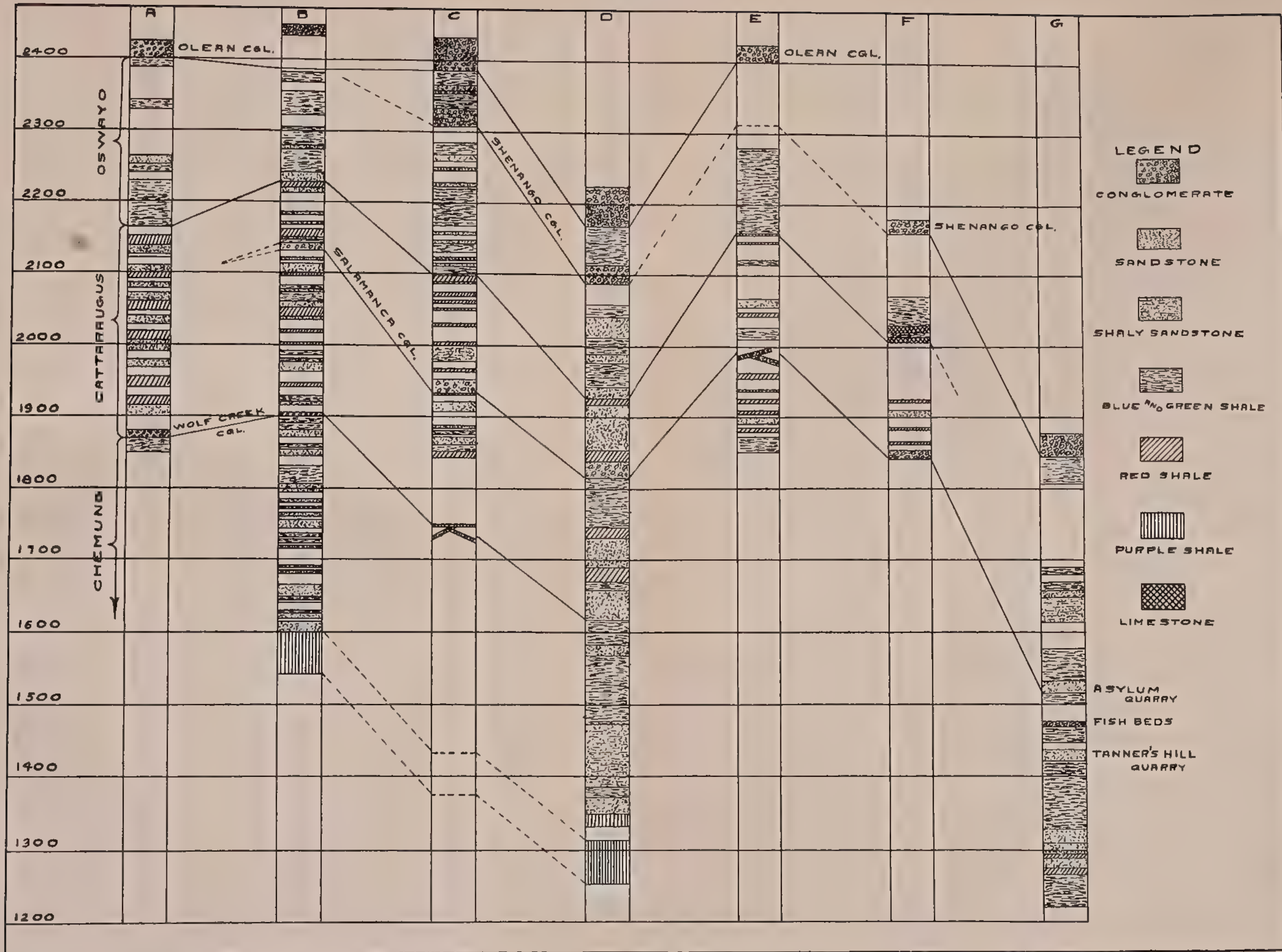
This skeleton is of a relatively small animal and is mounted in the State Museum.

Wayne county

Macedon

A few teeth in University of Rochester Museum. *H. L. Fairchild*

Plate 2



Columnar sections: A, Genesee rock city; B, Mt Hermon-Flatiron; C, Knapp's creek; D, Dennis well, Bradford; E, Limestone; F, Wolf run east of Corydon; G, Warren Pa. (the last after Randall)

Monroe county

1817 Rochester

Some remains were found in Rochester, in a hollow or watercourse. *De Kay. Nat. Hist. N. Y.; Zool. 1842. pt 1, p. 103*

1830 Pittsford

Tusk and one cervical vertebra. Bank of Irondequoit creek, 2½ miles from Pittsford. *J. A. Guernsey. Am. Jour. Sci. 1831. 19:358*

1838 Rochester

Along Genesee valley canal on Sophia street. Tusk, bones of head, several ribs, vertebrae, tibia and part of pelvis. These were found in gravel covered by clay and loam, and above them a deposit of shell marl. They were placed in the State Museum. *Hall. Geol. Fourth Dist. 1843. p. 364*

1866? Rochester

A few remains at Mount Hope cemetery. *H. L. Ward*

Ontario county

1885 Seneca

Excavated by Henry J. Peck on farm of Charles Gregory, where the bones had been discovered about 1882. Found beneath marl and diatom earth, about 3 feet from the surface. Sixty-five bones were obtained, mostly ribs and vertebrae with one tusk, 9 feet on outer curve, and styloid 1 inch longer than in the Warren mastodon. The antler of an elk was also found [*see* pl. 2]. The bones are now in the collection of Amherst College. *H. J. Peck*

Livingston county

1826 Geneseo

One half mile east of Geneseo. Tusks, head and lower jaw with eight teeth, pelvis and many other bones. *Jer. Van Rensselaer. Am. Jour. Sci. 1827. p. 381*

Subsequent excavations were made by James Hall and Sir Charles Lyell, and fragments of bones were found mixed with marl and fresh-water shells.

Date? Nunda

Ten bones and fragments, collected by Rev. Milton Waldo and presented by R. S. Fellows to Yale University Museum. *C. E. Beecher*

Date? Scottsburg

Twenty bones and fragments. F. H. Bradley and H. A. Green collectors. R. S. Fellows, donor. Yale University Museum. *C. E. Beecher*

1886 Fowlerville

Found in excavation on bank of the Genesee river, 80 feet above the water. Three or four teeth, tusks and other bones which were badly broken. *H. J. Peck*

Genesee county

1835-40 Stafford

Tooth found beneath muck on clay and sand. *Hall. Geol. Fourth Dist. 1843. p. 364*

1841 Leroy

Tooth in bed of marl, 3 miles south of Leroy. *Hall. Geol. Fourth Dist. 1843. p. 364*

1897 Batavia

Two tusks, part of skull with teeth, several vertebrae and ribs. *H. L. Ward*

Wyoming county

1877 Pike

Tusks, part of skull, some vertebrae and foot bones. Now in the Letchworth Museum at Glen Iris, Portage falls.

1886 Attica

Small tusk, ribs and other bones found in digging trench on Genesee street, in unlaminated clay at a depth of 2 to 3 feet, overlaid by clayey muck and loam. Beneath these bones were found several pieces of charcoal. In another part of the same swamp, under 4 feet of muck and 1 foot below level of the bones, was found a considerable quantity of charcoal with broken pottery. *Clarke. N. Y. State Geol. 6th An. Rep't. 1887. p. 34; 7th An. Rep't in N. Y. State Mus. 41st An. Rep't. 1888. p. 388*

Orleans county

1820 (?) Holley

Tooth found in excavation for Erie canal. *Hall. Geol. Fourth Dist. 1843. p. 364*

Niagara county

Date? Niagara Falls

Tooth in fine gravel and loam containing fresh-water shells. *Hall. Geol. Fourth Dist. 1843. p. 364*

Found in digging a mill race on Goat island, 12 or 13 feet below the surface. *De Kay. Nat. Hist. N. Y.; Zool. 1842. pt 1, p. 104*

Chautauqua county

1834 Jamestown

Part of jaw with two teeth. Found by John Hazeltine in muck "a little below the present level" of Chautauqua lake outlet. *Am. Jour. Sci. 1835. 27:166*

Associated with bones of elk. *De Kay. Nat. Hist. N. Y. Zool.; 1842. pt 1, p. 120*

1902 Westfield

On property of Mrs Alice Peacock, alongside Nickel Plate Railroad. The bones lay on pavement of heavy boulders and under several feet of black clayey muck. They consisted of 1 tusk (6 feet, 2 inches, and highly curved), 17 ribs, 8 pelvic and lumbar vertebrae, patella and parts of scapula and pelvis. *Clarke*

Cattaraugus county

Date? Hinsdale

Tusk with remains of deer (elk?) 16 feet beneath surface in gravel and sand. *Hall. Geol. Fourth Dist. 1843. p. 364*

Tompkins county

1870 (?) Near Ithaca

Five teeth and many fragmentary bones "in a deposit of modified drift." "The teeth indicate the existence of two or more individuals." *B. G. Wilder. Am. Jour. Sci. 1871. 2:58*

THE CAMBRIC DICTYONEMA FAUNA IN THE SLATE BELT OF EASTERN NEW YORK

BY RUDOLF RUEDEMANN

Introduction

With the progress of the investigation of the thick masses of shales, slates and flags, extending to the east and south of the great St Lawrence and Hudson river valleys from Gaspé to southern New York, or to the east of "Logan's line," it becomes more and more apparent, that Lapworth exhibited a prophet's intuition in predicting many years ago, that this mass, generally lumped together as Quebec and Hudson river groups, would be found to represent, formation by formation, the more or less calcareous series to the west and north of that line, from the Potsdam below to the Lorraine above.

In the last report of the state paleontologist the writer announced the discovery of three different graptolite zones, exposed at the Deep kill in Rensselaer county, which represent the Phyllograptus-Tetragraptus shales of northern Europe and Canada. From their identification with the Point Levis shales of Canada and by correlation with the corresponding zones of Europe, they are placed in the lowest Lower Siluric, and considered as representing the shaly development of the Beekmantown limestone and perhaps also of the Chazy limestone.

The continuation of the investigation of the slates of Rensselaer county has this year led, at Schaghticoke on the Hoosick river, to the finding of an outcrop of slates which contain a fauna known from the northeast of this continent and from Europe, and there considered as marking the closing stage of Cambric time. A very large quantity of excellently preserved material has been secured, the graptolitic part of which will be described in a forthcoming memoir. In this report, it is proposed to discuss only the geologic aspect of the discovery.

Description of locality and beds

The outcrop extends from the bridge of the Mechanicville-Johnsonville branch of the Fitchburg railroad, on both sides of the gorge for about one half mile. The river is forced, in this

Plate 1

Lower falls of the Hoosic river at Schaghticoke N. Y. Exposure of Upper Cambric Dictyonema slates

distance, to plunge three times over precipices caused by the rocks in question and to form the waterfalls, a part of whose great water power is utilized now in the mills of Schaghticoke. The outcrop is totally isolated, there being an interruption of three quarters of a mile to the outcrops farther above the river, near the powder mills of Valley Falls, the interval being filled by drift. Likewise the Schaghticoke beds are separated by a drift-filled interval from the masses of shales and heavy banks of " Hudson grit," exposed a little farther down the river. There is no doubt that the latter mass, which contains graptolites of the upper half of the Lower Siluric, is separated from the beds at Schaghticoke by a great fault, probably the same which farther south, for instance at Rensselaer, separates the Cambric and Trenton shales.

The Schaghticoke slates disappear also north and south of the river banks under great drift masses and do not reappear for considerable distances. It is however very probable or almost certain that they represent a continuation of the belt of Cambric rocks (shales, slates, quartzite and limestones) which are well exposed on the hills east of Troy and have become well known by Ford's discoveries of fossils. This belt has been traced and mapped by Walcott,[1] as extending as far as the Deep kill and been found by the writer to continue in fossiliferous beds still farther north, east and northeast of Melrose to within a few miles of the outcrop at Schaghticoke. As the latter lies also in the direct strike of these Cambric beds, it is fairly to be concluded that it is a northward continuation of that belt.

The Cambric beds of the slate belt of eastern New York have thus far furnished only fossils of the Lower Cambric or Georgian formation. The Dictyonema beds will, as we may anticipate, be shown to be equivalent to the highest Upper Cambric beds and may, hence, in a general way be said to represent part of the off-shore deposits of the Potsdam or Upper Cambric formation.

The entire mass of rocks, exposed for about half a mile in the gorge of the Hoosic river at Schaghticoke, consists of very fine bedded, black and prevailing dull greenish to olive silicious and

[1] Am. Jour. Sci. 1888. v. 35, pl. 3.

argillaceous slates with intercalations of thin limestone beds. The latter, consisting of hard gray, very fine grained limestone, are but about 1 inch thick and separated by black carbonaceous, argillaceous shales. These alternations of limestone bands and black, relatively soft shales, are well shown on plates 2 and 3. On plate 2 also the beds of green and black slates appear distinctly by their different shades, and the thin bedding can be noticed. The whole terrane, which by the width of the outcrop might be taken to represent a considerable thickness, is apparently nothing but a manifold repetition of the same series of beds in small, closely packed, and in all conceivable ways distorted folds. The latter appear distinctly on plate 3, which shows a part of the north bank of the river.

The lithologic similarity of the Schaghticoke beds with those of the Deep kill, containing the Beekmantown-Chazy fauna, is very striking; there occurring thin equally bedded, alternating, greenish and black slates and intercalated, thin, barren limestone bands. It is evident that there was no difference or break whatever in the physical conditions from the time of the deposition of these Cambric beds to that of the Lower Siluric beds; and the writer would not be surprised if in other localities they should be found to form a continuous series, as indeed is strongly suggested by the results of Professor Dale's investigation of the lithologic and stratigraphic characters of the slate belt.

Inclosed in these shales there have been found two different kinds of fossiliferous beds. The one is characterized by the occurrence of Dictyonema flabelliforme Eichwald, the other by that of Clonograptus proximatus Matthew. Both faunules have been observed in several places of the outcrop. This is partly due to a repetition of the same beds, but it is also obvious that neither of them is restricted to a single band, for one bed contained prevailing grown and half grown specimens of Dictyonema, while another bed, found a little farther down the river, carries nothing but the earliest growth stages. Likewise, at least two different beds, containing the Clonograptus faunule, have been noticed.

On account of the extremely disturbed condition of the beds, I have not been able to satisfy myself as to the relative position

Exposure of Upper Cambric Dictyonema slates at Schaghticoke N. Y Shows the thin limestone bands and green and black slates

of these faunules, but, as a few specimens of Dictyonema flabelliforme have been obtained from the Clonograptus beds, it is provisionally assumed that the faunules belong together as parts of a larger fauna and do not indicate sharply separated horizons.

The author and Mr van Ingen were not successful in determining the interval of rock between the two principal fossil beds or the thickness of the series of strata. All that could be established was that in one place the bed with Clonograptus is connected with a series of alternating black and olive-green slates, the latter characterized by worm tubes, which series has a thickness of 15 feet; that in another place a Clonograptus bed, presumably the same, is found overlying a series of 20 feet of like slates, which alternate with two series of thin, barren limestone bands [*see* pl. 2, which shows the lower series of limestone bands]. The principal Dictyonema horizon occurs in a 1½ inch band of peculiar lithologic character, it being a soft, strongly ocher-spotted black mud shale, which has a highly developed and, for the paleontologist, very unfortunate system of contraction joints. This band is separated by about 10 feet of black or greenish slates from a series of thin limestone bands in about the same number as that mentioned in connection with the Clonograptus bed. It is, hence, to be assumed that these two series of limestone layers are identical, and that the series of rocks containing these beds is at least 30 feet thick, but most probably considerably more. The fine black mud shale intercalated between the thin limestone bands, contains in another place great numbers of early growth stages of Dictyonema.

The principal Dictyonema stratum has been found to contain these fossils in such numbers that all surfaces of the thinly bedded band are entirely covered by colonies of Dictyonema flabelliforme Eichwald, *forma typica* (=D. sociale Salter) and var. acadicum. On a slab of similar lithologic character, lying loose on the bed, a valve of a Lingula or Lingulella, not sufficient for identification, was observed.

The Clonograptus bands contain:

Protospongia *sp.*	r
Dictyonema flabelliforme *Eichwald var.* acadicum *Matthew*	r

Clonograptus proximatus *Matthew* (Staurograptus dichotomus *Emmons*)	cc
Clonograptus *cf.* milesi *Hall*	r
Bryograptus lentus *Matthew*	c
B. spinosus *Matthew*	c
B. patens *Matthew*	c
Acrotreta bisecta *Matthew*	r
A. *cf.* belti (*Davidson*) *Matthew*	r

Notes on fossils

The Protospongia occurs mostly in large spicules (or bundles of spicules), consisting of pyrite and limonite, the four branches measuring 10 mm and more. Walcott has figured spicules of smaller size but like form from the upper portion of the Olenellus zone in Washington county, N. Y., and pointed out their similarity with Prostospongia fenestrata Salter. Patches of sponge tissue have been found, composed of rhombic meshes of nearly half an inch wide and thereby reminding one of the gigantic form Palaeosaccus dawsoni Hinde, from the base of the Levis beds. As a large surface of the bed containing these sponges is accessible, a further exploitation of the same in another season will probably furnish sufficient material for an exact determination of the relation of this sponge to the form mentioned and to the species described by Dawson from the Lower Levis beds at Little Metis.

Dictyonema flabelliforme Eichwald. There is some variation in the expression of the forms, and some of the varieties which have been recognized in other localities may also be discernible here. The great majority of the specimens however are clearly identical with Dictyonema flabelliforme Eichwald, *forma typica*, as it has been described by Kjerulf and Brögger. This is evinced by the rather open long meshes and the thin, slender dissepiments. Quite a number of forms possess rather fine meshes and may be comparable to the variety conferta Linnarsson. The mutation norvegica, which is said by Brögger to lie in a higher level at Väkkerö, and which is characterized by small, short, angular meshes and thick connecting dissepiments, is not represented in the Schaghticoke fauna. The variety acadicum, which was recognized by Matthew

Plate 3

Folds in the Upper Cambric Dictyonema slates at Schaghticoke N. Y.   North bank of Hoosic river

among the graptolites of the Cambric of the St John basin, is also present and recognizable by its small meshes and closely arranged thecae, 17 of which were counted in the space of 10 mm. But it must be added, that all these varieties occur intermingled in the same band and are connected by transitions.

Clonograptus proximatus Matthew. We will not enter here on a description of the development of this species, nor on its interesting structure, but defer that part of the investigation to the description of the fauna. But it is here pertinent to point out that Emmons had evidently this form before him when he described his Staurograptus dichotomus.[1] This species of Emmons has, ever since its publication, been considered with some distrust as a somewhat dubious form; and this with some justification, for Staurograptus is, compared with other graptolites, an odd looking fossil.

Staurograptus has been recognized again by Lapworth in the Cape Rosier (Quebec) zone [*loc. cit.* p. 168] and is referred to as the " dubious genus Staurograptus of Emmons." Gurley cites the genus in his list without any comment, evidently because he did not know what to make of the form. Our large material of Clonograptus proximatus, which contains all growth stages from the sicula upward, includes also Emmons's Staurograptus in unmistakable specimens and in great number. The peculiar branching of this form, which produces a cross in the center, instead of the crossbar (funicle) of the other Dichograptidae is the surest means of its recognition. Emmons's Staurograptus is but a very early growth stage of Clonogr. proximatus Matthew.

Emmons found his specimens in " the black Taconic shales of Rensselaer county, N. Y."

There occurs in the Clonograptus bed still another species of Clonograptus which is readily distinguished by its very loose branching and the small number of branches. This form is closely related to, if not identical with, Graptolithus milesi Hall.[2] The habit of both species is alike, and the thecae fail to show any differences; Clonograptus milesi has been found at Schaghticoke, though in much larger speci-

[1] American Geology. 1855. 1:10[illegible], pl. 1, fig. 21.

[2] Geology of Vermont. 1861. 1:372; v. 2, pl. 13, fig. 2–4.

mens than have been collected thus far, a difference which, however, is of no or little import. A differential character, however, which necessitates consideration lest hasty indentification might ensue, is the rapid twofold dichotomy in the Schaghticoke specimens, which, as in Clonograptus proximatus, leads to a crosswise branching in the center, while Clonograptus milesi possesses a "funicle" of considerable length.

On the other hand, Clonogr. milesi is closely related to Clonograptus tenellus Linnarsson (sp.), a species which is found in Scania in beds intimately connected with the Dictyonema flabelliforme slate. In view of this relationship of Clonograptus milesi, it is important to note that that species does not belong to the Quebec group, as it is usually cited,[1] but was derived from the slates at Georgia Vt. Hall says in regard to the provenience of his material:

The specimen from which the figures of this species were derived, is part of a boulder of Georgia slate, picked up in Monkton by Henry Miles of Monkton . . . The boulder was probably derived from the Georgia slate, either in Georgia or St Albans.

This citation is evidently not to be understood as meaning that Clonograptus milesi is a form of the Georgian or Lower Cambric formation; but it may be concluded with a fair degree of certainty that it came from Cambric slates lying somewhere near the top of the Cambric formation, and it is possible that this occurrence indicates the presence of another subzone in the Upper Cambric.

The discussion of the relations of the species of Bryograptus, cited in the list of the fossils of the Clonograptus bed, is reserved for the forthcoming description of the graptolite fauna of New York.

Lingula. A brachial valve of a linguloid form, about 9 mm long; perhaps referable to Lingulella concinna, a species described by Matthew from the Dictyonema horizon of McLeod brook, Boisdale, Cape Breton island. The Schaghticoke specimen appears more uniformly oval, but Mr Matthew's specimen is flattened out anteriorly and posteriorly, as appears from

[1] Miller's North American Geol. and Pal. p. 190.

Plate 4

Folds in Dictyonema slates, below woolen mills, Hoosic river, Schaghticoke N.Y.

his description, and may therefore have had a like shape. Our specimen is also somewhat larger than the Cape Breton form.

Acrotreta bisecta Matthew. There also occur types of an Acrotreta in the Clonograptus bed, the pedicle valve of which has been noticed only in a very much compressed state but still exhibiting the subcentric pedicle perforation. The brachial valve possesses the long, high, posteriorly enlarged (or dividing? in many specimens) median ridge, extending the entire length of the shell, and also on the cast, at least one pair of the minute pits, features which Matthew considered characteristic of his species Acrotreta bisecta, a form from the Dictyonema shales at McLeod brook, Cape Breton.[1] As our form also agrees in general outline and dimensions with the Cape Breton species, it may well be considered as identical with the latter. Matthew has also recognized this species among the brachiopods collected in the Dictyonema shale at the Navy island, St John N. B. as the form which he had formerly described as Acrotreta baileyi.[2]

Acrotreta cf. belti (Davidson) Matthew. There occur small orbicular corneous brachiopod shells in the Clonograptus bed, which on account of their small size and compression offer considerable difficulty to a definite determination. The pedicle valve shows a small circular pedicle perforation, the brachial valve, which is well preserved, three narrow septa and posterior muscle impression, as one finds in Linnarssonia transversa Walcott. As the latter species has lately been reunited with Acrotreta by Walcott[3] this form is probably also referable to Acrotreta. It seems to us to be identical with the minute shells found by Matthew in the Dictyonema beds (division 3c) at Navy island, St John harbor, and doubtfully referred by him to the Lower Tremadoc form, Linnarssonia belti Davidson.[4] It agrees at least with this St John fossil in size, outline and horizon. The internal characters of the latter are not well known.

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[1] Nat. Hist. Soc. New Brunswick. Bul. 19. 1900. 4:275, pl. 5, fig. 5a–g.

[2] Roy. Soc. Can. Proc. and Trans. 1891. 9:43.

[3] U. S. Nat. Mus. Proc. 1902. 25:577.

[4] Roy. Soc. Can. Proc. and Trans. 1891. 9:42.

The Dictyonema bed in Scandinavia

If we wish to arrive at a proper valuation of the importance of the Dictyonema horizon for the determination of the upper boundary of the Cambric, we must turn to northern Europe, where the subdivisions of the Cambric and Lower Siluric terranes have been studied most extensively, and the Dictyonéma slate has long been known. A lucid discussion of the relations of the Upper Cambric to the Lower Siluric has there been furnished by Professor Brögger in his paper, "Ueber die Verbreitung der Euloma-Niobe-Fauna (der Ceratopygenkalk fauna) in Europe."[1] Frech[2] has also discussed the problem of the upper limitation of the Cambric in an able and concise manner.

We learn from these treatises that in Sweden, and still more in the Baltic provinces of Russia, the boundary between the Cambric and Siluric is most sharply defined; that there is a break in the deposition, and that an entire change of the faunal associations leaves little doubt as to the boundary line. In Norway, however, as Brögger has well shown in his "Die silurischen Etagen 2 und 3 im Kristianiagebiet etc. 1882," a gradual transition takes place between the beds assigned to the Cambric in Sweden and to the Lower Siluric Ceratopyge limestone. Here the boundary, as Brögger states, has to be drawn by "characteristic peculiarities in faunistic features." The same distinguished author states [*loc. cit.* p. 79] in regard to the region of Christiania:

It can not be denied, that in the beds below the *Dictyograptus shale* the fauna bears throughout a primordial (Cambric) character; no graptolites, no cephalopods, no trilobites of the type of the characteristic Ordovicic genera (Asaphidae, Trinucleidae, Cheiruridae, etc., etc.). *Immediately above the Dictyograptus shale* itself we find simultaneously the first richer graptolite fauna (Bryograptus zone), the first Asaphidae (Symphysurus incipiens Brögger) and soon also the first cephalopods (Orthoceras atavus Brögger), in the Ceratopygenkalk, in the region of Christiania and correspondingly also in the fauna of Hof, of the Shineton shales, etc. There seems then to remain only the possibility of *placing the boundary at the Dictyograptus shale itself. I have hence united this with the Cambric.*

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[1] Nyt. Mag. for Naturvidensk. 1896. B. 35, S. 164–240.

[2] Lethaea Palaeozoica. 1897. 2: 30–34.

It is further stated, that, while to some degree the Niobe-Euloma fauna has still a mixed character, and contains primordial forms (specially Olenidae), the typically developed fauna of the Ceratopyge shale and still more of the Ceratopyge limestone in Norway is in *most prevailing degree a Lower Siluric fauna.*

Frech states that not a single species of trilobites goes beyond the Dictyonema shale into the Ceratopyge limestone in Sweden, in Norway Cyclognathus micropygus passes still into the Symphysurus bed, but not into the Ceratopyge shale; while, on the other hand, there appear not less than three new families and 13 genera above the Dictyonema bed. Therefore Brögger's claim appears fully justified:

The northern paleontologists, almost without exception, have always agreed to place the termination of the primordial fauna at the Dictyograptus slate; thus have done Linnarsson, Lindström, Nathorst, Tullberg, Holm, Lundgren, etc. in Sweden; that have I done similarly for Norway.

If one therefore will use the term "Cambrium" for the primordial-siluric sediments . . . then in my view one must also in England, Wales, France, America, etc., if this term shall be defined reasonably, *put the upper limit of the Cambrium there where the second,* to use Lapworth's name, the *Ordovicic* fauna begins, i. e. *immediately above the Dictyograptus slate.*

The Cambric of the Baltic provinces of Russia has been thoroughly investigated by Fr. Schmidt.[1] It shows considerable modification from the typical development in southern Sweden. The black shales so characteristic in Scandinavia have thinned out, and soft and seemingly not very old deposits appear in their place. It is divided by Schmidt into three stages, (1) the Blue clay, (2) the Ungulite grit, and (3) the Dictyonema slates, which form the characteristic uppermost zone of the system. Of this it is said:

This stage (3), the Dictyonema slate, is the highest member of our Cambrian series, and a very important one too, as it is the only indubitable connecting link between our Cambrian and that of Scandinavia. The Dictyonema slate has a thickness of from 1 to 10 feet and is exactly identical with the same stage as developed in Sweden and Norway.

[1] Geol. Soc. Quar. Jour. Nov. 1882, p. 516; Acad. Imp. Sci. St Petersburg. Mém. 2. 1889. v. 36.

As its characteristic species is cited Dictyonema flabelliforme Eichwald. In some places the Dictyonema slate shows also some other graptolites, which Schmidt believes to be identical with Bryograptus kjerulfi Lapworth. Also on the islands of Oeland (Moberg) and Bornholm (Johnstrup) the Dictyonema zone has been found, and in Belgium D. flabelliforme has long been known. It occurs there in the eastern part according to Malaise, and forms, as Dewalque asserts, as definite a horizon as it does in Wales and Scandinavia, in the lower part of the *système salmien* above the *système revinien*.

The Dictyonema bed in Great Britain

If we turn now to Great Britain, we find that there also the Dictyonema zone is well developed, in north and south Wales and in Shropshire, and that Dictyonema flabelliforme has long been known as Dictyonema sociale Salter. But the zone is placed here at the base of the large mass of dark gray slates, to which Sedgwick gave the name Tremadoc slates, and which he inclosed in his Cambric system. The bitter controversy between Murchison and Sedgwick involved the position of this terrane, like that of the Lower Siluric terranes, in much uncertainty, but it appears that the consensus of the British geologists is now to consider the Tremadoc as a part of the Cambric and thus to place the Dictyonema shale at about the base of the Upper Cambric. This is clearly and objectively expressed in Geikie's *Textbook of Geology,* 1892, p. 729, where we read:

It is at the top of the Tremadoc strata that the upper limit of the Cambrian or Primordial formations is now drawn in Britain . . . There appears to be more satisfactory proof of a distinct paleontological break at this stage of the geological record in Britain, or at least between the lower and upper part of the Tremadoc subgroup.

This proceeding, which, as an incidental result, separates the Dictyonema slate from the accepted base line of the Lower Siluric by 1000 feet of strata, is at variance with the views of the continental geologists, as is shown clearest by the publications of Professor Brögger and the new edition of the *Lethaea Palaeozoica*. It finds its explanation, besides the historic reasons,

in the fact that the relations of the Tremadoc to the Cambric, on account of the frequency of the Olenidae and Lingulellae in the former, are more striking than those of the Ceratopyge beds to the Olenus shales in Scandinavia.

Professor Brögger's careful revisions of the determinations of the English paleontologists [*see* his two works cited before] leave however little doubt, that, as Brögger concludes, the Tremadoc is to be correlated with the Ceratopyge beds, and hence the Dictyonema shale is to be regarded also in Britain as the terminal member of the Cambric series. The Dictyonema beds of the Malvern hills overlie the "Dolgelly group" and are placed by Callaway[1] below the "Shineton shales". The latter are considered by the same author as transitional between the Lingula flags and the lower Tremadoc, and thus still placed with the Cambric. Brögger, however, subjects the genera of the "Shineton shales" to a revision[2] and thus finds the latter to be equivalent to a horizon between the Dictyonema bed of Norway and the Ceratopyge limestone, approximately to his 3 aα—3 aβ; thus transferring them into the Lower Siluric.

The Tremadoc of north Wales has been worked out by Salter.[3] Brögger concludes as to the Tremadoc of North Wales (in "Ueber die Verbreitung etc." p. 42) that its largest part is equivalent to the Ceratopyge limestone horizons 3 aα—3 aγ, that the lowest part of the Tremadoc (with Dictyonema flabelliforme) corresponds already to his zone 2 e, the Dictyograptus slate of Christiania, while the uppermost part is perhaps equivalent to his 3 b, the Tetragraptus-Phyllograptus slate of Christiania.

The Tremadoc beds of south Wales (St Davids and Ramsay island) have become known, specially by the investigations of H. Hicks.[4] They differ considerably from the development in north Wales and in Norway, consisting of more than 1000 feet of gray, flaggy sandstones (St Davids) with few trilobites and

[1] On a New Area of Upper Cambrian Rocks in South Shropshire with a Description of a New Fauna, Geol. Soc. Quar. Jour. 1877, 33: 652 ff.

[2] Étages 2 and 3, p. 144–46.

[3] Mem. of the Geol. Sur. 1866. v.3. *See* edition of 1881 by Etheridge. *See also* A Monograph of British Trilobites (1864–83) in Pal. Soc. and Cat. of Camb. and Silur. Fossils. 1873.

[4] Geol. Soc. Quar. Jour 1873. 29: 39 ff.

a relatively rich lamellibranch fauna. In regard to these, Brögger disagrees with Hicks's view of considering their fauna as closely allied to the Lingula flags, but holds that the species of Neseuretus and the lamellibranch fauna point to a younger age and indicate a shallow water facies of the deeper water deposits of the Tremadoc of north Wales, with which he correlates these beds. The latter would, then, also have to be transferred to the Lower Siluric. They are also underlain by the Dictyonema slates; which accordingly would also in Wales denote the upper boundary of the Cambric, instead of falling within the Cambric as held by Salter, Callaway and Hicks.

Frech shares the views of the Scandinavian geologists as to the parallelization of the Scandinavian and British Cambrian-Silurian beds and holds with Brögger, that, though the relations of the English Tremadoc to the Cambric are more distinct than those of the Ceratopyge limestone to the Cambric on account of the prevalence of the Olenidae and Lingulellae, this fact is not of conclusive importance, as the Tremadoc is characterized, like the Ceratopyge limestone, by the appearance of those trilobite families which reach their principal development in the Lower Siluric. The Asaphidae, Lichadae and Ampycidae appear immediately above the Dictyonema slate; the Cheiruridae and Trinucleidae occur already in numerous representatives in the Upper Tremadoc; while the Olenidae and Conocephalidae of the Cambric are represented only by genera, not pertaining to the Cambric proper, as Ceratopyge, Euloma, Remopleurides, etc. Frech concludes that no doubt can be entertained as to the Lower Siluric position of the Tremadoc terrane and adds that the confusion existing in England in regard to the boundary of Cambric and Siluric excludes a solution of the problem by recognizing the rights of historic priority.

Professor Kayser also, in his *Geol. Formationskunde,* which has just appeared in a new edition (1902, p.48), holds that the Dictyonema bed forms the top of the Lingula shale and not the base of the Tremadoc shale, as the English geologists maintain, and further that the Tremadoc is a part of the Siluric formation; that hence, also in England, the Dictyograptus bed closes the Cambric formation.

In combining all the facts, viz that the underlying Dolgelly beds contain well known European and also eastern American Upper Cambric horizon markers, such as Peltura scarabaeoides, and the overlying Tremadoc terrane as distinctly Lower Siluric forms such as Calymmene blumenbachii, while the graptolites, on account of their pelagic life, have a wide horizontal and very limited vertical distribution and are themselves extremely exact indicators of synchrony, we believe it does not infringe on the rights of British geologists to conclude that the Dictyonema flabelliforme zone is in Britain as in the rest of Europe to be held as marking the top of the Cambric series, wherever it is observed.

The Dictyonema bed in North America

The first to publish a notice on the occurrence of the Dictyonema bed in America was, so far as we know, Sir William Dawson.[1] Sir William reports that Mr Richardson found at Matane "a bed of highly laminated black shale similar to that explored by Mr Weston a few years ago at Little White river, holding similar fossils in great abundance. Prominent among them is a beautiful Dictyonema, distinct from any of these found at Levis, and which on comparison with specimens presented to the museum by Prof. H. Alleyne Nicholson, appears so close in all its characters to D. sociale Salter, of the English Tremadoc, that it may fairly be assumed to represent that species in our fauna. It is well known that some good paleontologists regard D. sociale as only varietally distinct from D. flabelliforme of Eichwald from Russia. . . We might infer from this that the Dictyonema beds at Matane may indicate a horizon somewhat lower than any of those at Levis. Associated with the Dictyonema are many specimens of Dichograptus (corrected in handwriting for Didymograptus) flexilis and D. logani, or an allied form, and there are also fragments of an undetermined Tetragraptus."[2]

[1] Peter Redpath Mus. of MacGill Univ. 2d Rep. Jan. 1883. p. 16.

[2] We have no doubt that the species of Dichograptus cited here refer to the Cambric species of Clonograptus, either to Cl. proximatus Matthew or Cl. milesi Hall, specially as also elsewhere these Cambric Clonograpti have been first compared with the Beekmantown Clonograptus Dichograptus) flexilis.

It is added that in a neighboring bed there is a vast quantity of debris of trilobites, which seem to agree with the graptolites in indicating an Upper Cambric age, as they are apparently more nearly related to the trilobitic fauna of the Potsdam of Newfoundland, as described by Billings, than to that of Levis.

Sir William Dawson's conclusion of the presence of an Upper Cambric graptolite zone at the lower St Lawrence river has a few years later been verified by Prof. Charles Lapworth from material which had been submitted to him by the Canadian Survey. In his report[1] Lapworth recognizes three zones namely, in descending order, the *Griffin point* or *Marsouin river* zone (zone of Coenograptus gracilis) which corresponds to the Normans kill beds of New York, the *Ste Anne* zone (zone of Phyllograptus anna) which has been recognized in the middle of the three Deep kill graptolite zones, reported on in a former paper, and finally the *Cape Rosier* zone (zone of Dictyonema sociale and Bryograptus).

It is the last zone which this year has been found fully represented within the slate belt of eastern New York. We quote those remarks of Lapworth's on this zone, which seem important to our inquiry.

The oldest graptolitic zone represented is the Dictyonema sociale zone of Barrasois river (Cape Breton island) and of Cape Rosier, Gaspé. There are very few specific forms occurring in this zone, but they constitute together a very peculiar and distinct group, totally different from those of the remaining zones. The genera include Dictyonema, Bryograptus and Clonograptus, together with the dubious genus Staurograptus of Emmons. The Dictyonema appears to me to be absolutely identical with one of the forms referred by European (Scandinavian) geologists to Dictyonema flabelliforme Eichwald, which is also, so far as our present evidence enables us to judge, identical with Dictyonema sociale Salter, from the Tremadoc of north Wales.

To this zone belong the Barrasois river beds, those of Cape Rosier, of Little White river, of Grand Méchin point, of half a mile west of Long point, Matane, Little Capucin river, etc.

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[1] Preliminary Report on some Graptolites from the Lower Palaeozoic Rocks on the South side of the St Lawrence from Cape Rosier to Tartigo River, from the North shore of the Island of Orleans, etc. Roy. Soc. Can. Proc. and Trans. 1887. 4:167–84.

In Europe, this zone (or zones) occurs in the Tremadoc of Wales and the Tremadoc and Ceratopyge beds of Norway (Brögger) and Sweden (Tullberg). It is Upper Cambrian (as British geologists receive the term), and is probably represented in the West by a part of the Calciferous series of New York and western Canada. It is distinctly older than the graptolitic mass of the Point Levis beds. Not one of its forms has hitherto been figured from the Quebec group. It may occur at Point Levis, if the Calciferous is represented there. This is a point for future discovery to settle. In the meantime, however, it will be better to refer to the zone as the "Cape Rosier zone." Like the Levis Calciferous conglomerate beds, its fauna is made up of genera, partly Cambrian and partly Ordovician (i. e. partly Primordial and partly Cambro-Silurian).

The Cambrian age of the Dictyonema-bearing Barrasois river beds of Cape Breton island is demonstrated by their included Olenidae. The Dictyonema beds of Gaspé and Méchin can not be far above this Cape Breton zone. It is exceedingly probable, therefore, that, as in Cape Breton, the Dictyonema beds lie not far removed from the unconformable base of the fossil-bearing rocks of the district.

From further statements of the same author it can be concluded that he was averse to paralleling definitely the Cape Rozier zone with any formation of the New York series; for instance, in the summing up on page 174, we find under Cambric formations:

B^1 Fine conglomerates . . . and black slates (of Shickshock range).

B^2 Gray, red, brown and black shales with beds and bands of dolomite (Localities: Les Islets, coast south of Cape Rosier, etc). Fossils: Dictyonema, Bryograptus, etc. To this is added (B^1 and B^2 may, perhaps, represent both the Upper Potsdam and the Calciferous rocks of the western district of New York and central and upper Canada.)

In the table on page 183, the zone has been divided into two subzones, as follows:

B Dictyonema sociale zone (A). Shales of Cape Rosier, Little Whale river, Grand Méchin point, with Bryograptus sp., Staurograptus, Clonograptus, Dictyonema sociale Salt.

Dictyonema zone (B). Shales of Barrasois river, Cape Breton island, with Dictyonema sociale Salter, and Olenidae.

Dr Matthew's untiring and enthusiastic geologic investigations have later on led to the discovery of the Dictyonema zone

in the beds of the St John basin in New Brunswick.[1] Mr Matthew had, in full appreciation of the importance of D. flabelliforme for the determination of the upper boundary of the Cambric system, searched for years for this fossil in the black shales of division 3 (Bretonian) till the desired fauna was found on Navy island in St John harbor.

We learn from his important publications the interesting fact that in the St John basin, Dictyonema flabelliforme is not restricted to a single zone above the trilobite zone characterized by Peltura scarabaeoides, but that this Upper Olenus fauna extends in the Canadian Cambric into the Dictyonema zone, since its trilobites occur in lentils with layers included in shales which contain the Dictyonema. Matthew's practice has been to "regard the beds above the horizon to which these trilobites, so far as known, are limited, to be the true zone of Dictyonema, corresponding to the beds so designated in Europe, and to include the beds below, in which Leptoplastus, Sphaerophthalmus and Peltura are found, and which also contain Dictyonema, as a lower zone corresponding to the upper part of the Upper Olenus zone as developed in Wales and Scandinavia." He obtains thus the following zones of the Bretonian division of his St John group:

a Zone of Parabolina spinulosa

b Zone of Peltura scarabaeoides, contains also Dictyonema flabelliforme

c Zone of Dictyonema flabelliforme, typical development of the species

This is followed by an interruption of several hundred feet, the fauna of which is not known, and then by the Lower Siluric Phyllograptus shales.

These results obtained in the St John basin are important in several regards: they prove that Dictyonema flabelliforme is not everywhere restricted to a single graptolite horizon, but may range through a considerable thickness, and that its beginning falls distinctly into the hemera of the last trilobites

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[1] *See* On a New Horizon in the St John Group, in Canadian Record of Science, October 1891, p. 339–43, and Two New Cambrian Graptolites with Notes on other Species of Graptolitidae of that Age, in N. Y. Acad. Sci. Trans. Aug. 1895. p. 262–73, pl. 48 and 49.

of the Upper Cambric, as was clearly indicated by Lapworth's investigations. There can hence be no doubt that even where the Dictyonema zone contains no characteristic fossils of the Upper Cambric beds, it should be united with the latter and not with the succeeding graptolite faunas of the Lower Siluric.

Lately[1] Dr Matthew has also described the Dictyonema zone as overlying the Peltura zone from Cape Breton island.

Dr Ells's exhaustive *Report on the Geology of a portion of the Province of Quebec*[2] and the appended list of fossils by Dr Ami[3] prove that in the classical region of Logan's Quebec group the Dictyonema bed has not yet been observed. In citing Lapworth's correlation of the Dictyonema zone, and remarks (p. 48k) D i c t y o n e m a s o c i a l e zone is mentioned as "presumably Cambrian," and it is added "that Dictyonema has not, in so far as is yet known, been figured from the Point Lévis beds, the most westerly point from which it is reported being Matane."

Dr Ells is however inclined to doubt the correctness of Lapworth's correlation of the Dictyonema zone, and remarks (p. 48k) that Lapworth considers the Dictyonema zone from the presence of three species to belong to a lower formation than the Cambro-Siluric, and that of these two, a Clonograptus and a Dichograptus are apparently new and therefore not conclusive.

The presence of Dictyonema appears, then, to be the only reason why those portions in which this form is known to occur, otherwise intimately associated with strata holding Cambro-Silurian fossils, and which have so long been regarded as belonging to that group, should be removed from their apparently proper position in the series and placed in a different geological system; and, in view of the wide range Dictyonema is known to possess, we may well hesitate before deciding on such a separation, unless confirmatory stratigraphical evidence can be presented.

While this conservatism at the time of the publication of the report was justified to some extent, the facts brought out by Matthews's and Brögger's investigations serve to dispel all

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[1] Roy. Soc. Can. Proc. and Trans. 1891. p. 360, Nat. Hist. Soc. New Brunswick. Bul. 19. 1900. 4:219; *ibid.* no. 20. 1902. v. 4, pt 5, p. 377 ff.

[2] Geol. and Nat. Hist. Sur. of Canada. ser. 2. 1888. v. 3, pt 2, p. 5k–114k.

[3] *Ibid.* p. 116k–120k.

[4] *Ibid.* p. 45k.

doubts about the reliability of Dictyonema flabelliforme as an Upper Cambric index fossil.

Dr Ells determines the stratigraphic succession of the fossiliferous Quebec terrane (p.63k-64k; Cape Rouge section) as follows:

1 Black, green and gray shales, with thick bands of quartzose sandstone and occasional thin bands of limestone conglomerate. (Lower Sillery)

2 Mostly greenish, grayish and blackish shales with thin layers of gray sandstone. On the south shore of the St Lawrence, below Levis and also on the south shore of the island of Orleans, beds of conglomerate occur at about this horizon, in which the Lower Cambrian fauna occurs (Olenellus thompsoni).

3 Bright red shales, with thin bands of greenish and gray shale.

4 Red, greenish gray and black shales, with interstratified sandstones (Upper Sillery). Obolella pretiosa occurs in the upper part, near Sillery, and on the south side of the river Obolella pretiosa, Protospongia fenestrata, Phyllograptus typus, Tetragraptus serra and Lingula quebecensis.

5 Levis shales and conglomerates of Point Levis (Calciferous).

6 Black and grayish striped or banded shales, etc. (Upper Chazy or Lower Trenton).

7 The black or brownish bituminous shales and limestones of the city of Quebec and northwest side of the island of Orleans. The contained fauna is of Trenton-Utica age.

In regard to a correlation of the Cape Rosier or Dictyonema zone of the Lower St Lawrence shore, we find in Dr Ells's report (p. 82k) the following statement:

From Métis to Cape Rosier the great bulk of the rocks . . . belongs to the Sillery formation and much of it to the lower portion of that division, and entirely below what we regard as the fossiliferous or graptolitic Lévis formation of the city of Lévis and the southwest end of the island of Orleans. . . The rocks of Cape Rosier, in which the Dictyonema sociale, Clonograptus, etc., were found, as well as those 2 miles below Great Matane river, where similar forms occur, represent divisions 2 and 3 of the Cape Rouge section and the Beaumont shore, as well as of the strata on the south side of the island of Orleans, consisting of black, green and gray shales, with some red beds, together with the gray limestones and hard, grayish quartzites, while the associated limestone conglomerates are like those seen at Beaumont and at the east

end of the Island of Orleans. This character is maintained with great uniformity for the entire distance west of Marsouin, though at certain points the Sillery sandstones and red and green shales representing division 4 are more highly developed than at others. The rocks of this section would, therefore, both on the evidence of Professor Lapworth from the fossils, and from the comparison with the stratigraphical sequence of the Cape Rouge rocks, belong to a portion of the Cambrian system, probably representing the upper and middle divisions of that system, while the overlying Levis graptolitic shales and limestone conglomerates would represent the lower portion of the Ordovician or Cambro-Silurian system.

Dr Ells refers thus, on the evidence afforded by the stratigraphy and the graptolites, determined by Lapworth, the Sillery rocks (divisions 1, 2, 3 and 4) to the Cambric, and the Levis beds (division 5) to the lower Beekmantown.

Mr Walcott, in his review of Dr R. W. Ells's report[1] takes exception to some of Dr Ells's conclusions, as we see from his quoted statements:

The Cape Rosier *Dictyonema sociale* zone is regarded as the lowest of the graptolitic zones, and to indicate the horizon of the Tremadoc terrane of Great Britain. The Cape Rosier beds are referred to the Upper Cambrian by Professor Lapworth and Dr Ells, but, with our present knowledge of the Cambrian in America, I would refer them to the Lower Ordovician or to the lower Calciferous. The occurrence of the typical Calciferous fauna within one hundred (100) feet of the base of the Levis series, at St Joseph de Levis, points very strongly to considering the graptolitic fauna of the Upper Sillery to be of Calciferous age, if a comparison is made with the Phillipsburgh section.

Dr Ells refers the Sillery series to the Cambric, and in this I mainly agree with him, except that the upper portion is evidently a passage series between the Cambric and Lower Siluric. On lithologic and stratigraphic evidence the line would be drawn at the summit of the red shales. On paleontologic evidence, as furnished by the graptolites, I would include the upper portion of the Sillery red and green beds in the Lower Siluric, as I think they are above the typical Potsdam zone of America.

While we agree with this distinguished author in referring the upper part of division 4, containing *Phyllograptus*

[1] Am. Jour. Sci. ser. 3. 1890. 39:113.

typus and Tetragraptus serra, to the Beekmantown, the Cape Rosier Dictyonema sociale zone should, in our opinion, on the evidence adduced above from northern Europe and specially in view of the fact that in the St John basin it is found in the same beds with Cambric trilobites, be retained in the Cambric system. Dr Ells correlated this zone with divisions 2 and 3; as division 2 however contains Lower Cambric fossils, the Dictyonema zone should be expected at a much higher level, and we surmise that, if it is ever found in the Quebec region or Cape Rouge section, it will appear in the lower or middle part of division 4, or just below the line, where Walcott would terminate the Cambric system.

We have already stated in the report on the Levis beds of the slate belt that Professor Dale[1] recognized the presence of a terrane (horizon F) of ca, 35 feet of " gray, calcareous or very quartzose, finely bedded shales or black shales, with thin limestone beds", which he referred to the Beekmantown. Dr Gurley identified in the suite of fossils submitted to him for this terrane, Bryograptus, Dichograptus, Callograptus salteri? cf. Dendrograptus sp. and Dictyonema flabelliforme. In regard to this fauna it is said: " Several of these are regarded as probably of Calciferous age, which would place the horizon in the lowest part of the Ordovician. The European species of Bryograptus come from the Upper Cambrian. Dictyonema ranges from the Ordovician into the Devonian." The cited list of determinations gives us the impression that Gurley had before him fragmentary representatives of both the Cambric Dictyonema and Lower Siluric Phyllograptus zones. There is no doubt that, with his thorough knowledge of the graptolites, Dr Gurley would not have failed to recognize the zones mentioned, if such complete collections as the writer has, had been at his disposal. But any one who is at all acquainted with the slate region of Vermont and eastern New York, knows the extreme difficulty of securing anything but fragmentary collections in the intricately folded and mostly strongly cleaved beds. Exceptionally fortunate circumstances are necessary to permit the collection of superior material.

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[1] U. S. Geol. Sur. 19th An. Rep't 1899. p. 185.

The fact, that the Upper Cambric Dictyonema and the Lower Siluric Phyllograptus zones have apparently been united by Dale in his horizon F, demonstrates the lithologic identity of the beds, also observed by the writer and suggests, as stated before, the continuation of the same physical conditions from the Upper Cambric into the Lower Siluric time.

Possible subzones of the Dictyonema horizon

Whether the Dictyonema bed of New York will ever admit a further division into subzones, we are at present unable to surmise. In Norway Brögger has found that the mut. norvegica lies a little higher than the typical Dictyonema flabelliforme. In Sweden, Linnarsson, in 1871, had already discerned a zone with Clonograptus tenellus Linn., which was at first thought to lie below the Dictyonema flabelliforme zone, and to be associated with the Cambric trilobite Sphaerophthalmus alatus. Moberg[1] has, however, shown that this form lies above Dictyonema flabelliforme, and that the latter species occurs in layers immediately adjoining those with Sphaerophthalmus alatus.

Not very long ago Anton Nilsson and Axel Tellander[2] demonstrated that also in southern Sweden (near Fogelsång, Lund sheet) several zones can be discerned, namely, in descending order:

Zone with Dictyograptus norvegicus Kjerulf and Bryograptus kjerulfi Lapw.

Zone with Clonograptus cf. flexilis Hall.

Zone with Dictyograptus flabelliformis Eichw. *forma typica.*

Their observations verify Brögger's statement of the occurrence of Dictyonema flabelliforme var. norvegicum and of Bryograptus kjerulfi above the typical Dictyonema flabelliforme.

Matthew's results did not suggest to him a possible separation into a Clonograptus and Dictyonema zone. At Schaghticoke the two occur separated, but it is impossible to say posi-

[1] Sver. Geol. Unders. Afhandl. och upps. ser. C. no. 125. 1892. p. 1–16.
[2] Geol. Fören. Förhandl. no. 201. 1900. 22:421–26.

tively which lies higher. The occurrence of still another Clonograptus, Cl. milesi Hall, in black shales near Georgia Vt., indicates however that there may be Cambric subzones, characterized by forms of Dictyonema and the two species of Clonograptus.

These subzones may lead very gradually into the Tetragraptus and Phyllograptus zones of Beekmantown age; for the occurrence of a Clonograptus cf. flexilis Hall (a Point Levis form) between the two Dictyonema horizons reported by Nilsson and Tellander and the finding of a typical specimen of Bryograptus kjerulfi in the Tetragraptus shale of the Deep kill by the writer, as well as some other facts of distribution, would indicate the presence of such transitional zones between the Dictyonema and Tetragraptus beds. These would be equivalent to the Ceratopyge beds of Scandinavia, which there intervene between these graptolite beds, and to the Tremadoc of Britain.

Bearing of the occurrence of the Dictyonema bed on Cambric paleogeography

Messrs Ulrich and Schuchert have undertaken the task of elaborating a theory in explanation of the differences in stratigraphic succession and faunistic aspect of the Appalachian region and the area to the west of the same during paleozoic time[1]. The solution is found in the assumption of the presence of one, or at times, two parallel basins, separated by and inclosed in folds or barriers, and extending during the greater part of the Paleozoic over the territory of the present system of Appalachian folds. This theory not only serves to clarify a multitude of well known stratigraphic and paleontologic facts, but is also an incentive to investigations in further elaboration or modification of its details.

The facts presented in this paper furnish, on one hand, a new argument for the presence of such basin, and, on the other, appear to necessitate a modification in regard to the fixation of the date at which one of them, the Levis basin, is supposed to have originated.

[1] Paleozoic Seas and Barriers in Eastern North America. N. Y. State Paleontologist. An. Rep't. 1901. p. 633–63.

We have seen that the Dictyonema fauna is an undoubted Atlantic fauna. In North America it has been recognized in the St John basin of New Brunswick, on Cape Breton island and at several places on the south shore of the St Lawrence from Cape Rosier to Matane river. It has now been found as far south as Rensselaer county in New York and probably extends through the slate belt of New York and Vermont. It is hence, with the exception of the Levis region, where it has not yet been found, about coextensive with the present known territory of the Phyllograptus fauna. Like the latter, it has not been found either east or west of this long belt and is therefore to be assumed to have entered from the Atlantic, a basin of similar configuration and extension as the Levis channel, in which the Atlantic waters deposited the Phyllograptus fauna.

The Dictyonema shale is now however of Upper Cambric age, of which it represents the closing period wherever it has been found. It stands, lithologically and faunistically, in the same relation to the upper Potsdam of the Champlain region as the later Phyllograptus shales to either the Beekmantown beds, with which the writer correlated them, or to the Chazy beds, with which they are equivalent according to Ulrich and Schuchert's views. The Dictyonema beds represent, like the Phyllograptus shale, the graptolite shale facies of a trilobite-gastropod-bearing limestone (or sandstone in part) which adjoins the slate belt closely to the west and northwest. Ulrich and Schuchert see in the parallelism of the two different faunas and rock series (Phyllograptus shales and Chazy limestone) proof of the presence of twin channels, the Levis channel and Chazy basin, stating that "the respective faunas and the lithologic character of the deposits in the twin channels are so different that we can not doubt the thorough effectiveness of the Quebec barrier during the whole of Chazy time." Accepting, for the purpose of further argument, the correctness of the postulation of this barrier to explain the stated facts, it follows that a like barrier of equal extent must be postulated for the late Cambric time, and that the beginning of the elevation of this "Quebec" barrier, the northern extension of the "Appalachian valley fold", must be placed in late Cambric time, instead of at the beginning of

Chazy time. Toward the east the Levis channel was bounded by the Green mountains fold, which is supposed to have already emerged in middle Cambric time. This, as far as our knowledge goes, bounds also the upper Cambric graptolite shale.

Ulrich and Schuchert hold that the region of the later Levis channel had emerged during the Potsdam period [see the unclassified time scale, opposite page 658, *l. c.*]. This is in accordance with Professor Dale's conclusions,[1] who not only found the middle and upper Cambric beds to be missing, but also observed an unconformity between the Lower Siluric and Lower Cambric, indicating the emergence of the lower Cambric beds during the succeeding Cambric time. Our observations agree thus far fully with these results of Mr Dale's elaborate investigation with the exception of the closing upper Cambric time, represented by the Dictyonema shale.

Toward the west and north of this strip of upper Cambric land, forming the "Vorland" of the Green mountain fold, extended the more or less broad "St Lawrence channel," which effected the communication between the Atlantic and Mississippian seas, indicated by the distribution of the Dicellocephalus fauna.

The question whether this late Cambric "Levis" channel persisted throughout the Beekmantown period in this southern part of the present slate belt or the broader St Lawrence channel extended freely from the Adirondacks to the Green mountains is a problem, the solution of which is dependent partly on the exact correlation of the limestones occurring in the slate belt and partly on that of the three Deep kill zones of graptolites, corresponding to the Phyllograptus horizons of Europe. It will necessitate much detailed investigation to obtain conclusive facts and to decide between the differing views held in regard to these beds.

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[1] New York-Vermont State Belt, U. S. Geol. Sur. 19th An. Rep't. 1897–8.

ON THE SEDENTARY IMPRESSION OF THE ANIMAL WHOSE TRAIL IS KNOWN AS CLIMACTICHNITES

BY JAY B. WOODWORTH

In the course of an examination of the Pleistocene deposits of the Mooers quadrangle, including the township of Mooers, in Clinton county, N. Y., in the summer of 1902, I had my attention called to certain trails on the Potsdam sandstone in that town which are remarkable for their distinctness and association with terminal impressions not heretofore described. Having seen the trails of Climactichnites on a flagstone in the main street of the village of Mooers, I was led to inquire for the quarry whence the stone was derived, and, though I did not learn whence the slab came, I was informed by the postmaster of the tracks which it is the object of this paper to describe.

The trails (Climactichnites) described in this paper occur in the town of Mooers on the west side of the Mooers branch of the Delaware and Hudson Railroad a few rods south of what is known locally as Bidwell's crossing, on the land of Mr B. H. Palmer, at the first rock cut in the railroad north of Sciota and distant from that station somewhat less than 2 miles. The Potsdam sandstone is here practically horizontal and is exposed in the rock cut as a badly shaken, irregularly splitting series of prevailingly light colored sandstones. The track layer is exposed in the adjoining field in the wave-swept trough between two of the small beach ridges of the postglacial marine stage of the Champlain valley. The track layer, where its edge is exposed, has a thickness of 8 inches; it is traversed by several rudely parallel joints cutting all of the longer trails. The area exposed at the time of my visit was about 50 feet long and varying in width from a yard to over two yards.

The trails appear to have been first noted by the present owner of the land, who states that he cleared away some of the surface debris several years ago. Locally the trails are spoken of as those "serpents," and the impressions associated with them as "human footprints." A visit to the locality confirmed the surmise that the "serpent trails" are the ladderlike tracks known as Climactichnites. What, so far as I know how-

ever, is new is the occurrence at this locality of impressions at the end of the ladderlike trails, giving rise to the so called "footprints."

The trails called Climactichnites, first made known by Sir William E. Logan from Beauharnais, Canada, have since been found in Wisconsin and at Port Henry, in this State.

In the 42d annual report of the State Museum for the year 1888, an account with illustrations is given of the trails from certain of these localities, including the original description of Climactichnites wilsoni. For other references to the literature, the reader should consult Professor Hall's[1] report.

Opinion as to the origin of climactichnite trails has been extremely varied. From their occurrence in strata in which large trilobites are the only known animal remains with which the trails can be associated, there has been a prevailing belief, expressed by Sir William Dawson, Dana, and others, that the tracks are *probably* those of a crustacean if not a trilobite. Nicholson[2] has expressed the view that Climactichnites was probably formed by the same animal which produced Protichnites, and notes that Sir William Dawson observed that the living Limulus or horseshoe crab, when it uses its swimming feet, gives rise to a ladderlike trail. Sir William Dawson,[3] in his comparison with the trails made by Limulus in different modes of progression, notes that in the case referred to, where the platelike swimming organs pile up transverse ridges of sand, the lateral and medial lines which are produced at the same time are furrows and not ridges as in Climactichnites. T. Rupert Jones[4] was inclined to compare the trails with the galleries of burrowing crustacea. Professor Chapman[5] believed that both Protichnites and Climactichnites are really of vegetable origin. Still others, including Logan, have regarded the trails as having been made by a gastropod or an annelid.

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[1] Hall, James. N. Y. State Mus. Report of the Director. 1888. p. 25–34, plate opposite p. 34.

[2] Nicholson, A. Manual of Paleontology. ed. 2. 1879. 1:361.

[3] Dawson, Sir J. W. On the Footprints of Limulus, etc. Can. Nat. 7:271–77.

[4] Cited by Sir J. W. Dawson, p. 277.

[5] Cited by Nicholson, p. 361.

Plate A

The accompanying photographs, plates A and B, show the eastern end of the track area at Bidswell's crossing as photographed by Mr P. P. Sharples, in October 1902. Plate A is a view looking southward across the better defined trails. The point of the hunting knife rests at the end of one of the terminal impressions into which the trails merge. Other similar oval impressions are shown to the right and left. Plate B is another view of the same surface looking southeast along the two distinct trails seen in the right hand side of plate A.

The trails from Mooers agree in all essential characters with the original description of Climactichnites. It is to be noted that there are no traces of footprints and no medial furrow which may be attributed to the dragging of a tail spine in any portion of the trails which have been there studied.

The size of the trails is quite uniform in breadth. Measurements show them to vary between 5 and 6½ inches. The transverse ridges which give rise to the ladder structure are spaced about 1 inch apart, measured from crest to crest.

Each of these transverse ridges passes on the margins into the outside lateral ridges. Regarding, for reasons shown beyond, the terminal oval impression as in the direction toward which the animal was crawling in making the trail, it may be stated that the transverse ridges curve sharply forward at their margins to form the lateral ridges. This is quite evident in some portions of the trails, though it is not everywhere obvious. In figure 1, this feature is diagrammatically shown, together with the apparent overlapping of the successive ridges at their margins. The median ridge, in passing over which the transverse ridges bend rather sharply forward, as seen in the photographs and in figure 1, is a sinuous line not uniformly equidistant from the margins. Another important characteristic of the Mooers trails is the distinct pressing down of the sands in the making of the trail. By whatever process the transverse ridges were made, they were passed over and pressed on in the making.

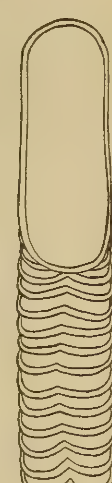


FIG. 1. Sketch of sedentary impression

The above cited observations warrant, it appears to me, certain conclusions.

1 The transverse ridges and their lateral extensions running forward to the next transverse ridge were made by the same movement of some organic structure lying transverse to the longitudinal axis of the organism.

2 The unity, identity and spacing of successive transverse ridges indicate that they were made singly and in succession, that their spacing indicates the forward stride of the organism, and that it went forward by a crawling, hitching movement.

3 The varying position of the median ridge with reference to the lateral ridges points to the conclusion that the transverse body was at the time characterized by a mesial sinus or upfold, and that the axis of this fold played to the right and left as a fold might in the flexible muscular foot of a crawling mollusk. In other words, the transverse ridges could not have been produced by the successive ambulatory movements of rigid swimming or gill plates, or by the scraping and pressing of the sand through the application to the bottom of the posterior margin of the pygidium of a large trilobite, unless in the latter case it be admitted that the animal was molting and had not grown a new rigid chitinous coat.

4 The pressed sand on the slopes and over the crest of the transverse ridges eliminates from the processes by which the ridges may have been made the backward push of the posterior margin of such an animal as the trilobite or of any transverse gill plate so placed as not to permit, under the condition in which the creature moved, the smoothing down of the successive ridges by some soft, pliable body still further *au derrière.*

An experiment was tried with a thin piece of board cut, as shown in figure 2, to represent the posterior margin of a trilobite or the inferior margin of some transverse swimming plate such as the paired gill plates which occur in the abdominal region of the limuloids, with the above restrictions in mind. In order to obtain the medial ridge, it was found necessary to cut the central sinus shown in figure 2. In this way, by moving the plate

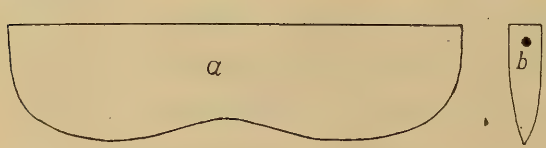


FIG. 2. Side (*a*) and end (*b*) views of wooden block used in experiment to produce ladderlike trails.

Plate B

in the manner indicated in figure 3, in imitation of the alternate contractile and extensile movements of a crawling organism, whose posterior margin the plate represented, it was possible to produce transverse ridges with the medial swell and the forward curved lateral ridges apparently overlain in succession by each new ridge. The whole surface of each ridge, except on the outer parts of the lateral ridges, was pressed down on both slopes, the posterior slope being steeper than the anterior slope in this process, just as is the case with Climactichnites. This difference of slope must necessarily arise where a transverse body is drawn forward, pushing up a ridge over which it is drawn in the making of the next ridge at its proper interval.

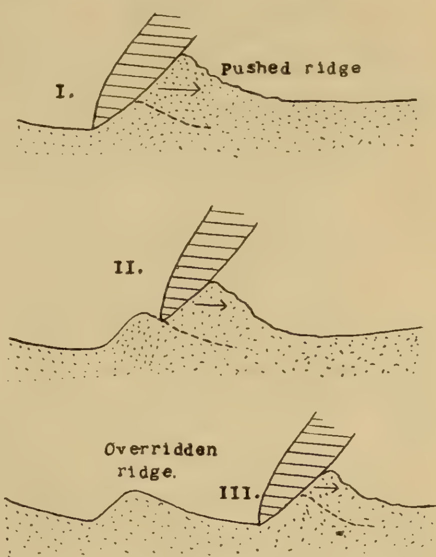


FIG. 3 Showing successive positions of scraper in experiment to imitate Climactichnite trails. (1) Position of scraper at end of long forward slope of a transverse ridge; (2) position of scraper after it has been raised up, overridden a transverse ridge, and begun to make a second frontal slope; (3) position as at 1, but showing cross section of completed transverse ridge in the rear. Movement in direction of the arrow.

The experiment with the artificial plate showed that, with such a rigid body, rigid ridges only could be produced; furthermore the ridges are at right angles to the margins, the central swell is equidistant from those margins, and, while the forward bend of the transverse ridge in passing over the central swell is slightly shown, the ridges themselves have not that oblique position which is frequently the characteristic feature of segments of Climactichnites. The comparison of the trails natural and artificial has therefore led me to the conclusion that Climactichnites could not have been made by the rigid carapace of a trilobite; moreover, there is no trilobite known in the Cambrian with an outline of the pygidium which could have produced the result, nor have recent discoveries concerning the natatory organs of the trilobites shown in the group the existence of natatory or gill plates such as are found in the more modern Xiphosura. The trail itself, therefore, it seems safe to state, was made by some flexible body like the mesially up curved

posterior margin of the expanded, retractile foot of a large crawling organism.

It remains to note the nature of the terminal impressions associated with many of the trails in the Mooers occurrence. In the first place, the postulate above made that the trails were made progressively toward these oval terminal impressions may now be explained by stating that, where the relation of the oval impressions to the trail can be made out, it is clear that the oval impression has obliterated a portion of the trail which once extended into the area of the oval impression; this is taken to mean that the animal which made the trail reached the end of the track and there, resting on the sandy bottom, left an impression of the outline of some marginally relatively rigid structure of the ventral surface. Had the organism started out from this oval area, it is obvious that the oval would have been partly effaced and merged into the trail. The complete adjustment of the oval terminal impressions to the trails thus becomes of extreme interest; for it must be that in these impressions there is a clue to the outline of the organism which produced Climactichnites.

The larger of the terminal impressions measured at Bidwell's crossing gave a length of 16 inches and a breadth of 6 inches.

The oval impressions are somewhat more depressed in the sand than the trails, particularly toward the posterior margin of the impressions [see plate A to the right of the knife]. In figure 1, a sketch is made of what was interpreted to be the general outline of the marginal groove of the oval impressions; but, either because the impressing body was tilted posteriorly downward so that it did not make so broad an impression anteriorly or because it was wider posteriorly than anteriorly, most of the distinct impressions are rather more pointed anteriorly than is shown to be the case in the diagram. There is also a broad swell in the center of the impressions. In the study of the forms which was made in the field, no traces of appendages or other ventral structures were made out. We are thus left to the trails, to the outline of the creature, and to the broadly undulating impression of the ventral surface to infer its nature.

Comparison with the Chitons. Professor Walter Faxon suggested to me, on seeing the drawing, figure 1, a comparison of the oval impressions with the outline of the ventral surface of the shell of the modern larger Chitons. Some of the Chitons are somewhat narrower anteriorly than posteriorly; but the oval grooved impression which their ventral surface would give has much resemblance to that of the sedentary impression of Climactichnites. The mantle of the Chitons extends beyond the shells; they have a powerful foot for attachment to rock surfaces; though habitually attached to rock surfaces, they can crawl very slowly over sand; they can roll themselves up into a ball, as did many trilobites; the retractile forward hitching movements of the foot of a large Chiton, moving inch by inch, might have given rise to the smoothened, cross-ridged trails known as Climactichnites; and the sedentary animal with retracted foot, the terminal impressions seen at Mooers. No other existing form seems so readily capable of producing the assemblage of phenomena. But it is equally possible that some large sea slug of the order of Aplacophora may have produced the trails and the terminal impression, though the modern representatives of these primitive gastropods are not littoral animals. Further than the suggestion of a molluscan origin for these terminal impressions and the connected trails, it does not seem possible at present to seek definite conclusions. It is possible that a more detailed study of the terminal impressions at Mooers with proper illumination will bring out faint traces of impressions not here described, and that from these diagnostic characters may be obtained.

The sedentary impressions terminate the history recorded by the trails. What became of the animal after making the sedentary impression is a matter of conjecture. A jellyfish or a naked mollusk such as Doris, becoming stranded, may wither away, leaving no recognizable vestige of its substance; this would hardly be the case with the Polyplacophora. It may be supposed that the animals which made the sedentary impressions on the Potsdam sandstones at Mooers floated away with the incoming tide. On the other hand, it is quite unlikely that in the porous sandstones of this area — for porous they must have

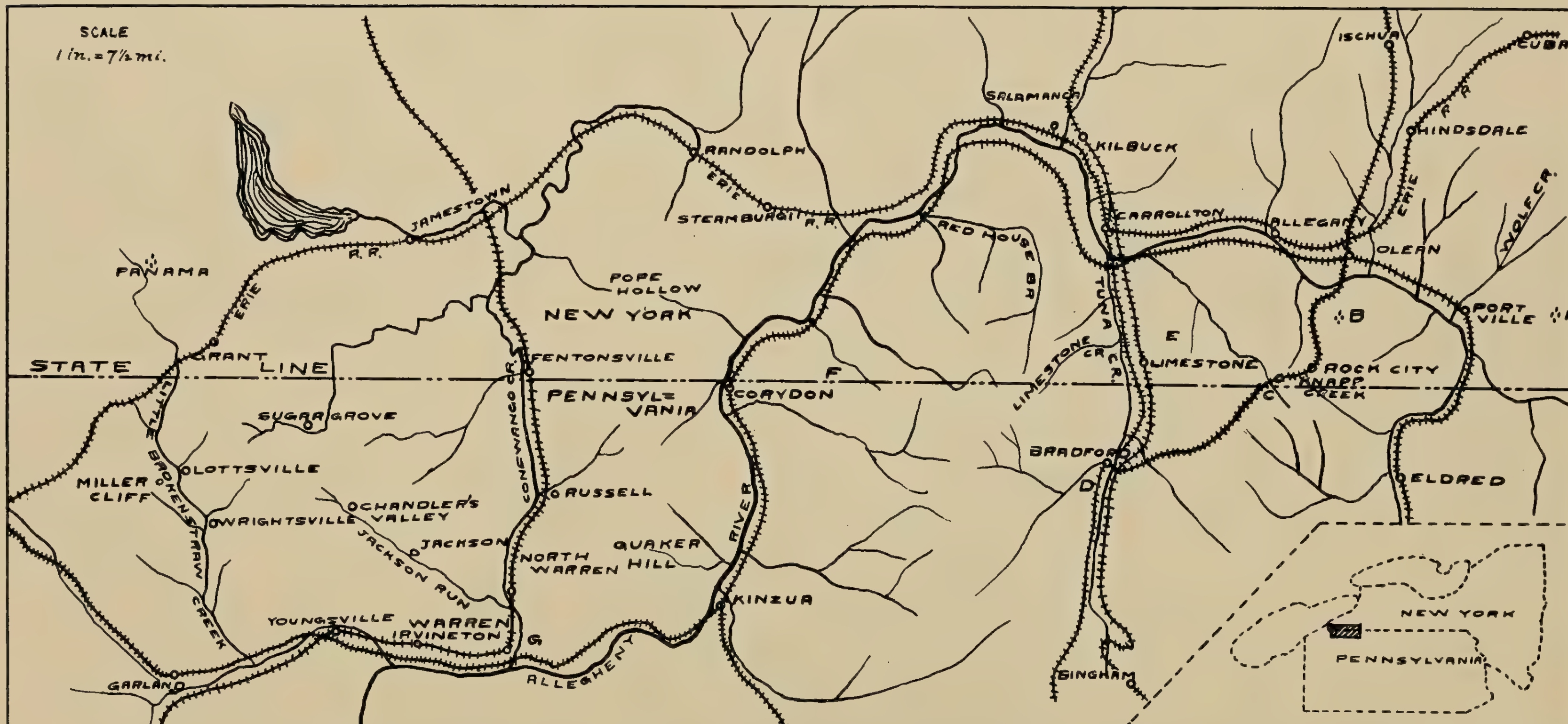
been a long time after their deposition — the shell structure of a mollusk would remain to the present time.

The manner in which several of the trails approach in a common direction and end close to each other in sedentary impressions is exactly what takes place in the case of the trails of many gregarious aqueous forms, which crawl up a beach or a partly exposed sand bar and rest on the dry sand. The presence of the trails leading to the sedentary impressions is conclusive proof that wave action was not concerned here in stranding the animals. The modern limulus, for instance, in the breeding season during the month of May on the Massachusetts coast, comes ashore in shallow bays, several individuals crowding the shore at the same place. The difference in the size of the terminal impressions and the convergence of the trails at Mooers suggest that more than one individual was concerned in making the trails here described.

Other occurrences of Climactichnites noted in 1902. Small partly effaced trails of Climactichnites were seen on the glaciated surface of the Potsdam sandstone in the road gutter on top of Covey hill, in Canada, about two miles west of the Covey Hill postoffice. The sandstone is exposed there for a long distance in the trenches on either side of the road. These tracks were seen on the north of the road.

A drifted block of Potsdam sandstone carrying narrow, straight, cross-ridged Climactichnite trails without a central ridge was found on the Mooers quadrangle near the Chazy river in the longitude of Irona N. Y. This specimen was sent to the State Museum.

Plate I.



Sketch map of the area here discussed and its vicinity in New York and Pennsylvania. The capital letters A to G mark the position of the sections given on plate 1

DEVONIC AND CARBONIC FORMATIONS OF SOUTHWESTERN NEW YORK

With stratigraphic map of the Olean quadrangle

BY L. C. GLENN

INTRODUCTION

Basis of paper. During the summer of 1900 the detailed geologic mapping of the Olean and Salamanca quadrangles in southwestern New York [*see* pl. 1] was undertaken by the United States Geological Survey in cooperation with the New York State Paleontologist, and the writer was placed in charge of the work. The work was continued and finished the next summer. Mr Myron L. Fuller assisted largely in the work on the Salamanca quadrangle during the latter season, and in both seasons Mr Charles Butts made extensive paleontologic collections from the two quadrangles and the adjacent region. Reconnaissance work was pushed southward to Bingham Pa. and westward across McKean and Warren counties to near Corry Pa.

Age of rocks and problems involved. The paleozoic rocks exposed in the quadrangle extend from about the middle of the Chemung up into the Carbonic. They consequently include the Catskill or its equivalent and the boundary or transition between the Devonic and the Carbonic. Eastward in both New York and Pennsylvania the distribution of the Chemung, the Catskill and the Carbonic rocks and their relationship to each other have received much study. Southward in Pennsylvania the Carbonic rocks have been studied and the lower Carbonic traced northward toward this region. To the west in Ohio the Carbonic and Waverly have been studied and traced eastward for some distance into northwestern Pennsylvania. The Olean-Salamanca region, however, has been an unknown meeting ground into which, when attempts were made to trace beds that were distinct to the east, the south or the west, the tracings became indistinct and the correlations uncertain.

Purpose of paper. It is the main purpose of this paper to describe briefly the stratigraphic succession found in the Olean-Salamanca region, to state the paleontologic conclusions so far reached as to the age of the formations, and the results of the efforts made to trace these formations into better known re-

gions southward and westward in McKean and Warren counties Pennsylvania.

Topography. Topographically the region is a maturely dissected one. The hills rise with steep slopes to an elevation of 500 to 1000 feet above the main stream levels. The northern portion of the two quadrangles is glaciated and exposures of rock in place are infrequent. Much of the southern portion and of the reconnaissance area in Pennsylvania is wild and wooded, and overgrown in many places with a dense tangle of bushes, briers and vines that both conceals exposures and renders the work of the geologist difficult and slow.

Structure. The dominant structure is that of flat lying beds dipping gently a little west of south at an average rate of about 30 feet a mile. Here and there the dip is locally increased or decreased and in the Olean and eastern Salamanca area just south of the Allegheny river it is for a short distance reversed. Some sharp minor folding occurs in the Olean conglomerate south of Olean along the high ridge extending from Flatiron rock to Knapp's creek and beyond. This folding is entirely taken up in the 1800 feet of shales that intervene between the Olean conglomerate and the Bradford oil sand which is penetrated by many wells at this depth and shows no sign of folding. In the Salamanca region some low rolls or folds with northeast-southwest axes were noted by Mr Fuller.

STRATIGRAPHY

DEVONIC FORMATIONS

Chemung beds

Description of Chemung shales and of Cuba sandstone lentil. The oldest rocks in the region are those near stream level in the northeastern part of the Olean quadrangle. They are typical Chemung shales and extend upward some 700 to 750 feet. Of these the very lowest beds consist of 30 or 40 feet of fine olive-green, argillaceous shale, seen best exposed in railway and other cuttings near Cuba. An excellent exposure may be seen a few yards east of the Erie depot at Cuba. In the railway cut 20 feet of it are exposed and nearly 20 feet more may be seen in the gutter by the side of the street leading down into the town. It is here fine grained and weathers into very small fragments.

When fresh the lower part is bluish in color and the upper part green, but it weathers to a rusty brown from its iron content. It is sparingly fossiliferous.

Immediately above these shales there is a sandstone 10 to 15 feet thick, most prominently exposed in and north of Cuba in a number of quarry openings. It is a medium to coarse grained, somewhat arkosic sandstone, usually of a light cream-color and smelling strongly of petroleum on freshly fractured surfaces. As seen in a quarry a few rods east of the Erie depot in Cuba there are exposed at the base 8 feet of thick bedded, hard, cream-colored sandstone, above them two feet of green and brownish shale, then two feet of sandstone abundantly fossiliferous. Above these are about 12 feet of sandy olive shale that weathers to a rusty brown, then 2 feet of thin-bedded flaggy sandstone, above which are seen to the top of the opening 8 feet of interbedded shales and thin shaly sandstone plates. The lower 10 feet of the sandstone are quarried. In places the stone is stained with iron along joints and seams. Fossils occur rather abundantly in certain layers and in the coarser parts an occasional small quartz pebble is found. Other quarry openings are found in and near Cuba. At North Cuba the rock has been opened at several places and probably furnished the stone for the dam of the old canal reservoir there. The region in which it occurs above water level is glaciated and almost all outcrops are concealed by till. It extends from North Cuba and Ischua, however, down Oil and Ischua creeks to near their junction where its dip carries it beneath flood plain level.

A solitary exposure of sandstone having the same general appearance, situated at about the same geologic horizon, and carrying the same characteristic Cuba sandstone fossils is found in a Buffalo, Rochester and Pittsburg Railway cut north of Great Valley on the Salamanca quadrangle and has been correlated with the Cuba sandstone. All other exposures along Great Valley creek are entirely concealed by the drift so that its areal extent there is unknown.

From its exposure in quarries in and around Cuba this sandstone is known as the *Cuba sandstone.* It is regarded as a lentil in the Chemung formation.

Above the Cuba sandstone lentil the Chemung is composed of green and brownish argillaceous and sandy shales, interbedded here and there with thin shaly sandstones. With the probable exception of certain dark purplish shales to be described presently, the individual beds of neither the shales nor the shaly sandstones usually retain their thickness or individuality or possess any lithologic character that would enable any one of them to be traced and identified for any distance. The nearest approach to persistency in these variable beds is found in a sandy zone about 200 feet above the Cuba sandstone. A number of quarries have been opened in the past on some argillaceous sandstones at this horizon. The stone is fine grained and soft and is more accurately described perhaps, as a shaly sandstone that varies into an indurated mudstone. When exposed to the weather the outside scales off or cracks and seams develop, so that in each quarry opened it was soon found to lack durability. All these quarries are abandoned today but at intervals along either valley wall of Oil and Olean creeks from one a few miles above Hinsdale that furnished material for locks for the old state canal to ones to the west and to the south of Olean may be seen the old openings. But even this sandy zone, persistent as it is as a whole, well illustrates the variability in detail of these Chemung strata for often in one quarry face there is visible a complete change along the bedding plane from one lithologic phase to another, so that as a whole these Chemung shales and argillaceous sandstones are only regular in their irregularity and intergradation.

The one exception as regards the rapid variability of these shales is found in certain dark purple or chocolate colored shales about 325 to 350 feet below the top of the Chemung. These are largely sandy and interbedded with thin plates of very shaly sandstone often of about the same color. They sometimes have a reddish cast but it is always a very dark brick red never a bright red. They seem to be widely persistent and are found in many well borings to the south. Their top occurs in the Dennis well at Bradford Pa. at a depth of 712 feet.

In a few places south of Cuba some faint traces of oolitic iron ore are found in the shales a hundred feet or more above

the Cuba sandstone. They seem to be of local development and even in this region are scarcely worth mentioning. At a number of horizons the shales become locally calcareous and a bed 6, 8, or even 10 inches thick may pass into a very impure limestone that where exposed on the surface has usually been leached out into a honeycombed mass of brachiopod casts and molds. These thin beds weather into soft rusty blocks or chunks that are often very conspicuous on the surface. In many places the sandy shales and thin shaly sandstones, specially near the top of the Chemung, are stained bluish black by manganese. Ripple markings are common at various horizons and in a few places what may possibly be obscure mud cracks are found. Minute mica scales often fleck the parting planes of the thin shaly argillaceous sandstones. As a rule the Chemung strata are abundantly fossiliferous. Brachiopods and lamellibranchs are the most abundant forms while in some of the abandoned quarries above mentioned sponges are also to be found.

Cattaraugus beds

Wolf creek conglomerate lentil. A marked change in the conditions of sedimentation caused the deposition of a conglomerate that is most prominently developed on Wolf creek and is known as the Wolf creek conglomerate. Its pebbles are predominantly flat or discoidal and hence it is also often called the "flat pebble" conglomerate in contradistinction to the Olean or "round pebble" conglomerate occurring higher in the series. The pebbles are mostly of vein quartz though a few are of red jasper. They vary in size from an inch or two in diameter down to ones of coffee or wheat grain size. Pebbles of the larger size are not abundant. The average size is perhaps less than a half inch in diameter. The mass of the rock is as a rule a coarse, loosely cemented, cross bedded sand sometimes bleached white but usually stained yellow or brown by iron. In some places on Wolf creek it becomes locally massive, and projects from the valley walls in ledges 15 to 20 feet high from which large blocks are shed into the valley below. One of the most prominent characteristics of this conglomerate is its rapid variation in thickness. Nowhere more than about 20 feet thick, it often in a few hundred yards thins

down to a few inches in thickness. It was at first thought that these thicker portions might mark an old stream channel but a careful mapping of them failed to reveal any relation to a possible stream course. Notwithstanding its rapid variation in thickness it was found to be a remarkably persistent stratum over the Olean and the eastern part of the Salamanca sheet and was the key rock for determining the stratigraphy of much of this region. Its maximum thickness of about 20 feet is found in only a few localities and these are on Wolf creek. Elsewhere in the Wolf creek region it is frequently found 5 to 10 feet thick, but over by far the larger part of the area in which it is known to occur in these two quadrangles it is only from a few inches to a foot or two thick and consequently is not a conspicuous stratum and is rarely exposed in a natural outcrop. Its horizon in numerous places is determinable only by tracing up a hillside loose pieces on the surface to the highest point at which they can be found and then working along at this elevation till the upper limit of loose material is well established. Even in a part of the region where it is, as a rule, very inconspicuous it may for a short distance thicken materially, as for instance northeast of Carrollton where it is locally 10 or 12 feet thick, and it is entirely possible that in the portion of the Salamanca quadrangle where it is not known to occur and where its horizon is indicated by the dotted geologic boundary line between the Chemung and the Cattaraugus there may be here and there spots where a few inches or a few feet of it are to be found. The beds occasionally contain a fair to good representation of marine fossils the assemblage of which is characteristic of this horizon. It marks the first prominent change in sedimentary conditions in the region and is regarded as a lentil marking the base of, and belonging to, the Cattaraugus formation.

Shales and sandstones. The deposition of the Wolf creek conglomerate was succeeded by conditions that caused the deposition of bright red shales interbedded with green or bluish shales and fine grained, greenish gray, thin bedded, micaceous sandstones that together extend upward through an average interval of 300 to 350 feet. This portion of the stratigraphic column in which bright red shales occur, and

which extends upward from the base of the Wolf creek conglomerate lentil in the Olean region to a limonitic shale presently to be characterized, is regarded as a formation and to it the name Cattaraugus is given. Two other conglomerate lentils occur in it, the Salamanca and the Kilbuck.

The bright red argillaceous shales of the Cattaraugus are entirely different from the dark brick red or purplish shales of the Chemung and need never be confused with them. No bright red shales occur anywhere in this region below the Wolf creek conglomerate but they do appear within a few feet above it. They are usually fine grained and argillaceous though in many places they become sandy and may locally pass into a thin red argillaceous sandstone. Specially does this transition occur in the southeastern part of the Olean area and in eastern McKean county, Pa. It is not certain that the individual beds of red shale are persistent or hold their thickness for more than short distances, but it is certain that as one goes westward into the Salamanca region and southwestward into Warren county, Pa. the beds of red shale tend to disappear. Their disappearance appears to be due not to a lack of deposition in this area at that time, nor to their once having been deposited and subsequently removed from the entire region by erosion before the deposition of the overlying formations but to their grading over westward and southwestward into deposits of other than red color. The stratigraphic equivalents of the red shales are as a rule present to the westward but their color has changed to olive-green, blue or drab. At the same time there is some evidence that erosion occurred in this region after the deposition of the beds containing these red shales as will be seen somewhat later.

The lighter colored shales interbedded with the red ones vary from fine blue mud shales to light or dark green sandy ones. Along with the shales are greenish gray, medium to fine grained, soft, arkosic sandstones often thin or cross bedded and with their parting planes flecked with mica particles. By the oxidation of their iron content these sandstones weather into a red soil just as the red shales do. These sandstones have been quarried and sawed into flagging at the Cook quarry a few miles south of Olean, though no work is now being done

at this place. The individual beds of sandstone do not seem to be persistent except for short distances. There is found, however, in a number of places in the Olean region a rust-colored sandstone layer filled with limonitic concretions and containing fish remains, but whether these exposures belong to one persistent horizon or not is uncertain. To the southwest near Warren Pa. fish remains are known to occur at several horizons.

Fossils. After the deposition of the Wolf creek conglomerate which contains in its upper portion specially a marine fauna, fossils rapidly disappear and the red and green shales and the fine micaceous sandstones generally yield but few or, for considerable intervals, no forms. In many places, specially in the sandstones, fossils are entirely wanting. Conditions as a whole were evidently unfavorable to animal life while these beds were being deposited. Some fish remains occur as mentioned above and the Salamanca and Kilbuck conglomerate lentils are fossiliferous.

Salamanca conglomerate lentil. The Salamanca lentil occurs at about the middle of the Cattaraugus formation. It thins out and disappears to the eastward, not being known to occur on the Olean quadrangle to the northeast of the Allegheny river and Oswayo creek. South and west of this line it occurs in the Olean area as a hard gray sandstone 10 to 15 feet thick, which becomes coarser and thicker westward and passes into a massive conglomerate on the Salamanca quadrangle. The sandstone phase is well exposed in a number of small quarries on Mount Hermon just south of Olean where it is locally known as the Mount Hermon sandstone. It is there a medium to a coarse grained sandstone carrying an occasional small quartz pebble. It is generally cream-colored to gray though some layers are dotted with innumerable small rust-colored spots that have resulted from the decomposition of iron pyrite. The bedding here is usually regular and the thickness of a given bed uniform for at least some distance. The layers of from 8 to 16 inches in thickness are separated by thin shale films or partings that render their removal easy. It weathers into hard, white, parallel-sided blocks that are pierced by many vertical fucoid tubes or stems. These fucoids are often very prominent and are

a characteristic feature of the weathered blocks in the Olean region.

Its massive conglomeritic character is best developed in the Salamanca region and may be well seen up Limestone and Irish brooks, along Red House creek, at Salamanca rock city where it weathers into great blocks, and at numerous other places.

In thickness, coarseness and massiveness it is also variable though not as markedly or abruptly so as the Wolf creek. In its more massive phase it is often strongly cross bedded and in places is separated into two benches with a shale parting between. The pebbles are mostly of vein quartz and the great majority of them are distinctly flattened like those of the Wolf creek and, like the latter also, they include an occasional one of red jasper. Even when coarsest and most massive the pebbles do not appear as prominent or form as large a proportion of the mass as they do in the Olean conglomerate. The bulk of the rock consists of a coarse, gritty sand. The average size of the pebbles is small and they are usually distributed through the mass of the rock not uniformly but in thin streaks along the planes of the cross bedding.

The difference between the flatness of the pebbles of the Wolf creek, the Salamanca, the Kilbuck and the two thin conglomerates just below the Olean and the roundness of the pebbles of the Olean itself was first noticed by Carll[1] whose explanation of their flatness as due to beach action would seem to be correct. He regarded older shore deposits lying to the north as the source of the pebbly materials. As the presence of the occasional jasper pebbles among the flattened quartz ones in all of the conglomerate beds in the region below the Olean or round pebble conglomerate gives sufficient gounds for concluding, it is believed by the writer that the coarse materials of these lower, or flat pebble conglomerates, were derived from the Lake Superior region and were transported eastward along the shore by the waves and long shore currents of the Devonic and Carbonic seas, the flattened or discoid form so characteristic of the pebbles of these lower conglomerates being produced by their to and fro motion along the beach during this long eastward journey.

Carll, J. F. Geol. Sur. Pa. Rep't I_3, p. 60, 61; I_4, p. 190–92

The round or ovoid pebbles of the Olean conglomerate which contains no jasper pebbles, it is further believed were not transported along the beach but were brought down from the ancient land masses to the north and east and were rolled over and over and rounded by the stream currents that carried them into the Carbonic sea. The flattened pebbles were beach fashioned, the rounded ones stream made. The total maximum thickness in the Olean-Salamanca region is rarely over 30 feet and probably never exceeds 40.

Much confusion and uncertainty has arisen in the Salamanca region as to the number of conglomerates present beneath what has generally been called the Subolean. This is specially true of that region bordering the valley of the Tunangwant or Tuna. Various correlations, some of which, however, were recognized as provisional, have been made for the same outcrops, and different outcrops of the same conglomerate have often been regarded as belonging to different horizons.

The names Salamanca, Panama, Pope Hollow, Wrightsville and even Subolean (?) have all been applied in this region to the same conglomerate some of them being regarded by some as synonyms but the belief being prevalent that two or three conglomerates are present in the Tuna section. [1]Lesley for instance, believed there is lowest a Salamanca (Panama?) conglomerate, above it a Tuna-Pope Hollow-Wrightsville conglomerate horizon and above that an Ireland-Subolean (?) one. J. F. Carll[2] believes that at least 225 feet above the Salamanca conglomerate the Tuna occurs and is the equivalent of the Ireland Subolean (?) of Lesley and probably the equivalent of the Pope Hollow-Wrightsville conglomerate found farther west. F. A. Randall[3] recognizes in the Tuna region a lower or Panama and an upper or Pope Hollow conglomerate and thinks it probable that the Salamanca is the equivalent of the Pope Hollow. The lower conglomerate found by Randall northeast of Carrollton and up Baillett brook and perhaps in a few other neighboring localities is the Wolf creek here locally much thickened as com-

[1] Lesley, J. P. Geol. Sur. Pa. Summary Final Rep't. 2:1531–32.

[2] Carll, J. F. Sec. Geol. Sur. Pa. I_4: 203–8.

[3] Randall, F. A. Preliminary Report on Geology of Cattaraugus and Chautauqua Counties. N. Y. State Geologist An. Rep't. 1893. p. 713–21.

pared to its usual development in this region. His higher conglomerate is the Salamanca.

The Salamanca, the Panama, the Pope Hollow and the Tuna are the same conglomerate and Lesley's supposed third or Subolean (?) conglomerate at Ireland near the head of Irish brook is also an excellent outcrop of the Salamanca, here quite massive. The confusion has mainly resulted from assuming a regular dip for the Salamanca and then concluding that a conglomerate found too high or too low at a given locality for the calculated position of the Salamanca at that place belonged to a different horizon. Dips, however, are not regular in this region. A local northward reversal of dip occurs near the mouth of the Tuna and again just southeast of Salamanca and several small rolls or gentle irregular folds with northeast southwest axes occur in the Salamanca area. These irregularities render such dip calculations misleading.

Kilbuck conglomerate lentil. On the Salamanca sheet there is found in the Cattaraugus formation a third conglomerate lentil lying 50 to 70 feet above the Salamanca conglomerate and called by Mr Fuller the Kilbuck. It has much the same flat pebble character as the underlying Salamanca. It is not over 10 to 15 feet thick as a maximum but in places is quite massive and weathers into large flat blocks that, where topographic conditions favor, form a pavement over considerable areas. It is best developed northeast and east of Kilbuck and extends as far east as the ridge at the head of Tenmile creek. It is also found north of Salamanca and on the high ridge south of Salamanca and east of Red House brook as far south as the head of Irish brook. A small area occurs on the ridge east of the Tuna and north of the head of Leonard brook. It is thus seen to be of local development, but has possibly added to the difficulties of making correct correlations in this region.

Probable unconformity. The top of the Cattaraugus formation is difficult to determine with exactness in most places since its upper portion consists of soft shales and it is succeeded by other soft shales. Exposures are in consequence poor except along roadways or pipe lines. Numerous measures, however, that are deemed reliable have been obtained of the thickness of that part of the formation which lies above the top of the

Salamanca conglomerate lentil. A comparison of these figures shows that this thickness frequently varies irregularly and very materially within short distances. The interval from the top of the Salamanca to the top of the Cattaraugus near Flatiron is 65 feet, southwest of Knapp's creek it is about 145 feet. In the Dennis well at Bradford Pa. it is 84 feet. At the head of Chipmunk creek it is about 90 feet. East of Chipmunk it is 110 feet in one place and in another near by more than 145 feet. At the head of Leonard brook it is 180 feet, northward at the head of Baillett brook it is 220 feet, while still north beyond the Allegheny it is only 100 feet on the knob east of Carrollton. In several places in the Limestone-Irish brook region it is 100 feet or less while just north of Rice brook it is at least 230 feet. On the southeast side of upper Red House brook it is 110 feet while on the northwest side it is over 210 feet. At the triangulation station southeast of Salamanca it is 215 feet or less, a mile and a half north it is 240 feet or more.

It is not thought probable that mere local variations in the thickness of the strata of the Cattaraugus could be rapid enough and great enough to account for the irregular variations that have just been mentioned in the thickness of that part of this formation which lies above the Salamanca conglomerate lentil. It seems more probable that the upper surface of the Cattaraugus is irregular because of erosion and that there is consequently an unconformity at this point representing an erosion interval between the Cattaraugus and the succeeding Oswayo.

CARBONIC FORMATIONS

Oswayo beds

Composition. The close of the Cattaraugus stage was marked by the cessation of the deposition of red shales in this region. After what is believed to have been an erosion interval it was followed by the deposition of olive-green to rusty colored sandy shales, with here and there thin sandstone layers with limonitic seams or incrustations. These greenish, limonitic shales constitute the Oswayo formation. Its thickness varies from 160 to 250 feet, the average being near the latter number. Conditions now became more favorable to the existence of life and, in contrast to the usual barrenness of the red shales

below, the Oswayo contains in many places a fairly good representation of marine invertebrates, prominent among which is Camarotoechia allegania, which serves as an excellent horizon-marker.

Limestone layer. A few feet above the base of the Oswayo shale is found in a number of places in New York what seems to be a persistent layer of very impure limestone. It is only one or two feet thick and in places is separated into two layers with several feet of shale between. This limestone is composed of innumerable fragments of badly broken brachiopod and other marine shells. It might almost be termed a shell conglomerate. In places it also includes bryozoan remains. One of the best exposures is seen in an abandoned railway cut at the burned power-house on the electric road about a mile north of Olean rock city. It is again found just off the Salamanca quadrangle on both the present and the abandoned line of the electric road southwest of Knapp's creek in several places. Near the head of Nichols run on the hill southeast of Limestone and at the head of the western branch of Red House brook along an abandoned railway grade just beyond the edge of the Salamanca quadrangle it is again found. It is probably the same as a very similar limestone which the writer has examined at a number of places in McKean county, Pa. and which is called by Ashburner[1] the Marvin creek limestone with the suggestion that it is probably the same as the Lower Meadville limestone of Crawford county.

On the Olean quadrangle a few small areas of Oswayo shales are found on the highest crests north and east of Portville, but they are mainly found on the highest ridges south of the Allegheny river and in this region extend up to the base of the Olean conglomerate. Near their top they become sandier and the number of thin limonitic sandstone plates increases.

On the Salamanca quadrangle the largest areas of Oswayo shales are found south of the Allegheny river. They occur on almost every prominent ridge. North of the river the only areas of any size are those on the ridge crests on either side of Tenmile creek.

[1] Ashburner, C. A. Sec. Geol. Sur. Pa. Rep't R, p. 68–69.

At Olean rock city there are some traces of grits some forty or more feet below the base of the Olean conglomerate. Nowhere on this quadrangle, however, have such gritty beds been found exposed in place and at several points good exposures of this part of the section are to be seen, as for instance on the road from Fourmile down into Fourmile creek valley.

The trace of grit at the rock city may be the equivalent of one or the other — probably the lower — of the two thin conglomerate beds found interbedded with shales and lying just beneath the Olean conglomerate westward at Knapp's creek and elsewhere on the Salamanca quadrangle, and which will presently be described. If so, these coarser beds have so fined down and lost their characteristics that it becomes impossible to separate them on the Olean quadrangle from the Oswayo shales beneath and both are on this quadrangle accordingly mapped together under the name of the Oswayo. It is very probable that over most of the small area on the Olean quadrangle where the upper part of the Oswayo shale occurs the very topmost beds, which are the equivalent of the grits and interbedded shales westward, were eroded before the deposition of the Olean and consequently that even if this part were lithologically separable from the Oswayo there would be very little of it to map.

Knapp beds

On the Salamanca quadrangle there are found beneath the Olean conglomerate two thin conglomerates interbedded with shales that are lithologically very similar to the underlying Oswayo shales. These are doubtless in part at least the equivalents of the grits and shales just beneath the Olean at rock city and which are included in the Oswayo there but which evidently thicken and coarsen westward till they are capable of differentiation as the Knapp formation. These beds are not usually well developed on the Salamanca quadrangle and have been found in only a few areas along the southern edge. Southwestward in Pennsylvania a more prominent conglomerate known as the Subolean is situated in a similar stratigraphic position beneath the Olean from which it is separated by from 25 to 50 feet of shales. It is known over a large area and extends according to the Pennsylvania geologists westward into Ohio where it is

known as the Shenango conglomerate. It with the associated Shenango shales is probably the equivalent of this Knapp formation.

The coarser part of this formation is usually a loosely cemented conglomerate with small well smoothed quartz pebbles of flattened discoidal shape that only in places becomes massive. It is frequently highly limonitic and in most places where examined was fossiliferous. The fossils consist of marine invertebrates and plant stems of various kinds. The shales are sandy and olive-green or rusty brown and in several places have been found to contain marine invertebrates.

The most eastern exposure of these beds is found at Knapp's Creek Station. Here there are two coarse beds separated by a varying thickness of shale. In the gutter beside the road leading from Knapp's Creek Station down into the head of Fourmile creek, in the interval from 20 to 40 feet below the station level, is found a thin bedded gritty to pebbly sandstone heavily charged with iron and containing marine invertebrate fossils. The layers are separated by partings of blue clay shales. A few hundred yards west of the station along the electric road just before reaching the summit there is a second sandstone about 40 feet higher than the first one, the interval between being occupied by sandy ferruginous shales. This sandstone is hard and gray and rings under the hammer. It is bedded in layers a few inches thick, some of which contain a few pebbles. The layers are separated by ferruginous sandy shales. It is also fossiliferous bearing among other forms Syringothyris. Above it are perhaps 20 feet of shale before the base of the Olean is reached. Beyond the summit one passes down through the same succession in reverse order, the upper sandstone being about 5 feet thick and more conglomeritic, the underlying shale being 20 feet thick and the lower coarse bed consisting of 20 feet of thin conglomerate and sandstone interbedded with shale, the pebbles being chiefly of wheat grain to coffee grain size. Both beds are again fossiliferous. These beds — specially the upper one — are found exposed at intervals along the ridge westward nearly to Harrisburg. At Harrisburg and to the northwest they have been cut out and several small areas of

Olean conglomerate lie at a lower elevation than these underlying beds do just to the south and east.

The best development of this formation in the Salamanca quadrangle is found on the ridge southwest of Limestone near the Pennsylvania line. These two thin conglomerates again occur just beneath the Olean. They are very well exposed along the pipe line crossing this ridge. Each is more massive and more conglomeritic than in the Knapp's creek area. The upper one at least is fossiliferous. They are each 10 to 15 feet thick. The shale interval between varies from 30 to 40 feet in thickness and is fossiliferous, containing among other forms Syringothyris again. There are about 25 or 30 feet of shale between the upper conglomerate and the base of the Olean. Farther south and west only one conglomerate known as the Subolean has been seen by the writer beneath the Olean and the shale interval is usually great enough to make it seem most probable that this one conglomerate is the lower of the two in the above mentioned localities, if both have not united westward.

In some other places also these beds seem to have been cut out by erosion before the deposition of the Olean conglomerate, as, for instance, on the ridge north of the head of Irish brook, where Olean caps the hill but with no sign of an underlying conglomerate beneath. The same thing is true at Miller's cliff in Warren county, Pa., where the Olean occurs, but beneath it the Subolean is wanting. There is consequently believed to be an unconformity between the Olean and the underlying formations in this region and from differences of level in the base of the Olean as exposed in outcrops often but short distances apart, the floor upon which the Olean was deposited must have been a very irregular one.

Pottsville beds

Olean conglomerate. Next comes a massive round pebbled conglomerate widely known as the Olean conglomerate. In texture the Olean often varies quite rapidly both horizontally and vertically. In some places or in some beds it is scarcely more than a coarse sandstone with a sparing development of pebbles, while at other places or in other layers at the same place, it is almost entirely composed of rounded quartz pebbles. If any rule holds good the lower part is more frequently con-

glomeritic and the upper part a coarse, cream-colored sandstone that weathers white on exposure. It is almost always strongly cross bedded. The pebbles are well rounded and in contrast to the flattened or discoidal pebbles of all of the underlying conglomerates in the region are predominantly ovoid in shape so that the Olean is frequently referred to as the "round pebble conglomerate." While flat pebbles do occur in it, yet the proportion of round or ovoid ones is so great that the distinction is good. These pebbles vary in size up to two or three inches in diameter though the average diameter is somewhat less. Most of them are of vein quartz; a few are of a hard, dark gray slate; none are of red jasper.

They are loosely embedded in a very arkosic sandy matrix, in portions of which there is considerable iron which has formed thin limonitic streaks or crusts through the rock and resists disintegration much better than the arkosic cement does.

Etched quartz pebbles. Pebbles of vein quartz embedded in surfaces made of such limonitic crusts are frequently found much etched or corroded. The only part played by the limonitic crust is the holding of the same pebbles exposed on its surface for some time till the etching agent has had time to greatly corrode them. The nature of the etching agent is not certainly known. It is generally thought to be some one of the humic acids that result from plant decay.

The best examples of such etching seen in the region by the writer are in shallow depressions in which water stands after a rain on the upper surface of the blocks that make up the Genesee rock city. These huge blocks are on the top of a high crest in a field with only one tree near that rises above them. The upper surface of the blocks is bare except for a very few submicroscopic plant forms which may possibly by their decay furnish a corroding agent, though this impressed the writer when examining them as not being an adequate cause.

The next best example of etching is found at Olean rock city. Here both the cause and one rather diagnostic step in the process seem more satisfactorily determinable. On the under surface of overhanging portions of the rock so situated

that they could not be wet by rain or receive drippings from any surface above were found many small well etched pebbles of vein quartz. These under surfaces of the rock were very appreciably moist, however, even on a hot summer day. This moisture was derived partly by seepage of contained moisture down through the loosely cemented rock itself and partly by direct condensation of moisture from the atmosphere, since from their sheltered position these surfaces remain quite cool even on the hottest days. If due to an organic acid of decomposition, this acid must have reached the etched under surface by soaking through some 30 or 40 feet at least or rock. Why it has not attacked and corroded the many quartz pebbles passed on its way through the rock, but has preferred to wait till it has reached the under surface before becoming chemically active seems explicable on the theory advanced by Dr C. W. Hayes[1]. The acid was probably humic and so was comparatively inert till it had come into free contact with the atmosphere on reaching the underside of the ledge, where it absorbed nitrogen from the air forming azohumic acid which has a strong affinity for silica and at once began corroding the quartz pebbles. These somewhat exceptional conditions at Olean rock city seem most readily explicable on this theory and they in turn lend additional strength to the theory itself.

Disintegration of the Olean is as a rule very rapid and talus slopes occur everywhere so that the base is rarely or never exposed. Numerous well borings have penetrated it, however, on the Olean quadrangle and give an accurate measure of its thickness there which is usually between 60 and 70 feet, though in one well it is 90 feet. It occurs on the highest hilltops in the southern part of the two quadrangles, in a number of small detached areas and is well known southward in McKean county and westward in Warren county in Pennsylvania.

Above the Olean conglomerate at rock city are found a few feet of thin, sandy, ferruginous shales in which some years ago a thin coal bloom was exposed in grading a road. It also belongs to the Pottsville.

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[1] Hayes, C. W. Solution of Silica under Atmospheric Conditions. Geol. Soc. Amer. Bul. 8:213–20.

AGE OF FORMATIONS

Paleontologic work. The extensive collections of fossils made by Mr Charles Butts were studied by him at Albany under Dr J. M. Clarke's supervision. Prof. H. S. Williams has also studied similar collections made some years ago by himself and his assistants in this region and the paleontologic facts stated below concerning faunal affinities are those ascertained as a result of the investigations of Dr Clarke, Dr Williams and Mr Butts. Additional facts bearing on the paleontologic problems of the region may soon be expected as a result of the further studies now in progress by Drs Clarke and Williams.

The conclusions which the writer has drawn from these paleontologic facts he alone is to be held responsible for.

The shales extending from the lowest exposures up to the base of the Wolf creek conglomerate contain an abundant Chemung fauna and are considered to be of Chemung age. The first Carbonic life forms appear with the incoming of the Wolf creek conglomerate and from this point up to practically the base of the Olean conglomerate at Olean rock city where the last Devonic forms disappear, there is a mingling of Devonic and Carbonic forms, the Devonic slowly decreasing, the Carbonic slowly increasing. The essential fact so far as the life of these Cattaraugus and Oswayo formations is concerned is that there is an overlapping of Devonic and Carbonic faunas. With this essential fact recognized the position at which the boundary line between the Devonic and the Carbonic shall be drawn becomes, in some measure at least, a matter of convention.

It might appear best for some reasons to draw this line at the base of the Wolf creek where Carbonic forms first appear and consider both the Cattaraugus red beds and the Oswayo and Knapp formations as Lower Carbonic. This would make the top of the Chemung the top of the Devonic and would make the Subcarbonic average about 600 feet thick in this region.

Because of the thickness of these red beds and their reasonably certain stratigraphic equivalence with the red beds of the Catskill to the east, and because of the unconformity believed to exist between the Cattaraugus and the Oswayo, the writer prefers to draw a provisional boundary between the Devonic and the Carbonic at this point. This would make the Subcarbonic

300 to 350 feet thick here and would make the top of the red beds the top of the Devonic.

All of the facts bearing on this difficult Devono-Carbonic boundary problem will not be at hand till paleontologic researches from both the Devonic and Carbonic starting points have been finished and detailed stratigraphic work has been carried eastward, southward and westward to connect with better known and more clearly differentiated areas in these directions. Hence this boundary is to be recognized and accepted as distinctly provisional only and is subject to such change as later investigations of the stratigraphy and paleontology of the adjacent regions may warrant.

The Olean has been agreed on as Carbonic but there has been considerable difference of opinion as to just what portion of the Carbonic it represents, though the weight of opinion has been in favor of its age being Pottsville. Very recent field studies by Messrs M. R. Campbell[1] and David White are regarded by them as definitely establishing its Pottsville age. It is still doubtful, however, as to what part of the Pottsville it represents. It may be the equivalent of either the Connoquenessing or of the Sharon. If it be equivalent to the Sharon, the few feet of overlying shale represent the Sharon shale and the thin coal bloom the upper Marshburg coal. If it be the Connoquenessing, the overlying shale and coal belong to the Alton or Mercer coal group. Detailed work to the south and west will be necessary to settle this point.

RECONNAISSANCE

A reconnaissance was made southward into McKean county, Pa. and then westward on both sides of the state line nearly to the western edge of Warren county, Pa.

Wolf creek conglomerate. South of Ceres the Wolf creek conglomerate is well developed along King's run, being in places fully 20 feet thick but weathering into pieces a few inches to a few feet thick. It dips under stream level a short distance north of Glenn postoffice. West of this point on the road to Eldred it appears at the upper fork of Newel creek and is again seen on the road just south of the upper fork of Barden brook, whence it may be traced to Eldred where it outcrops 120 feet

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[1] Personal letters from Mr M. R. Campbell, Ap. 18 and 27, 1903.

above railway level. It is represented in the Dennis well at Bradford by part or all of the 35 feet of sandstone with base at 1620 feet above tide. West of Bradford it is not satisfactorily identified. It probably loses its character even as a sandstone and soon entirely disappears westward.

Salamanca conglomerate. No traces of the Salamanca conglomerate were found south of Ceres or near Eldred. In the Dennis well at Bradford it is represented by the 23 feet of sandstone with "a few pebbles," having its base at 1817 feet above tide. West of Bradford it is found up Marilla creek and west of Marilla summit it occurs on Corydon creek. It is again found west of the Allegheny river both in Pennsylvania and south of Steamburg in New York and from its elevation, its position in the section and its lithologic character as well as by its tracing westward, the writer concludes that it is the same as the Pope Hollow conglomerate, which may be traced south from Pope Hollow past Fentonville and Russellsburg by exposures at intervals along either valley wall of the Conewango to the Asylum quarry at North Warren. It may be traced westward up Rhind's run by numerous exposures to a point on Jackson's run about 2 miles east of Chandlers Valley. All exposures from here to Sugar Grove are covered with glacial till but it is quarried a short distance west of Sugar Grove, is found just above the mouth of the Lottsville well no. 1[1] and may be traced at intervals along the Little Brokenstraw valley northward past Grant station till there can be no doubt of its being the Panama conglomerate. Tracing it southward from Lottsville it passes about 225 feet beneath the Wrightsville conglomerate at Wrightsville and is doubtless the pebbly sandstone found "about 100′ from the surface" in the Rocky Hollow well[2] about a mile northeast of Wrightsville. It seems probable that farther south this Salamanca-Pope — Hollow-Panama conglomerate may be the same as the third Venango oil sand if that sand has a northward representative at all.

In this northwestern part of Warren county the shales and thin soft micaceous sandstones that extend for a couple of hundred feet above the Panama conglomerate weather into a steep

[1] Carll, J. F. Sec. Geol. Sur. Pa. Rep't I_4, p. 199, 232.
[2] Carll, J. F. Sec. Geol. Sur. Pa. Rep't I_4, p. 236.

but smooth slope that is highly characteristic and bears when cleared, as it usually is, a characteristic vegetation. These shales with their characteristic topography and vegetation often aided in tracing the underlying Panama where it was not exposed or had even dipped somewhat beneath drainage level.

Wrightsville conglomerate. The Wrightsville conglomerate can not be identified with the Panama, but lies about 225 feet higher in the section. It seems reasonable to suppose that it is the equivalent of the Venango first sand as is believed by Lesley, though no attempt was made by the writer to trace it to a connection with that sand.[1]

Olean and Subolean conglomerates. The Olean conglomerate is found on Mount Raub near Bradford and occurs on the hills south of Bradford decreasing gradually in elevation till it is last exposed in the Buffalo, Rochester and Pittsburg Railway cut just north of Bingham station as an irregularly bedded sandstone. Here it dips under the plateau surface. No examination was made of the region south of the divide where it doubtless reappears. The Olean conglomerate and the Shenango conglomerate and shale are traceable westward across Warren county. All occur on Quaker hill and at Pike's rocks and elsewhere. The Olean appears at Miller's rock but the Shenango seems to have been cut out there just as its equivalent, the Knapp formation, has been near the head of Irish brook and elsewhere as previously noted.

Local pebble beds. During the reconnaissance locally developed pebbly beds usually only a few inches in thickness were found at several points. These thin pebbly beds occupy no definite horizon but apparently may occur anywhere in the Cattaraugus or Oswayo formations. In no case was any one of them found to be persistent or to possess any stratigraphic importance. They were revealed by chance in some unusually good exposure in a railway cutting by the roadside, or along a stream bank and would ordinarily have entirely escaped observation. It is possible that at some point in the region

[1]For the opinions of the geologists of the second Pennsylvania survey on the correlations of the various members mentioned in the preceding paragraphs *see* White, I. C., Report Q_4, p. 99–116; Carll, J. F., Report I_3, p. 57–80, I_4, p. 195–208, p. 304–8 (F. A. Randall); Lesley, J. P., Summary Final Rep't, 2: 1493–1536.

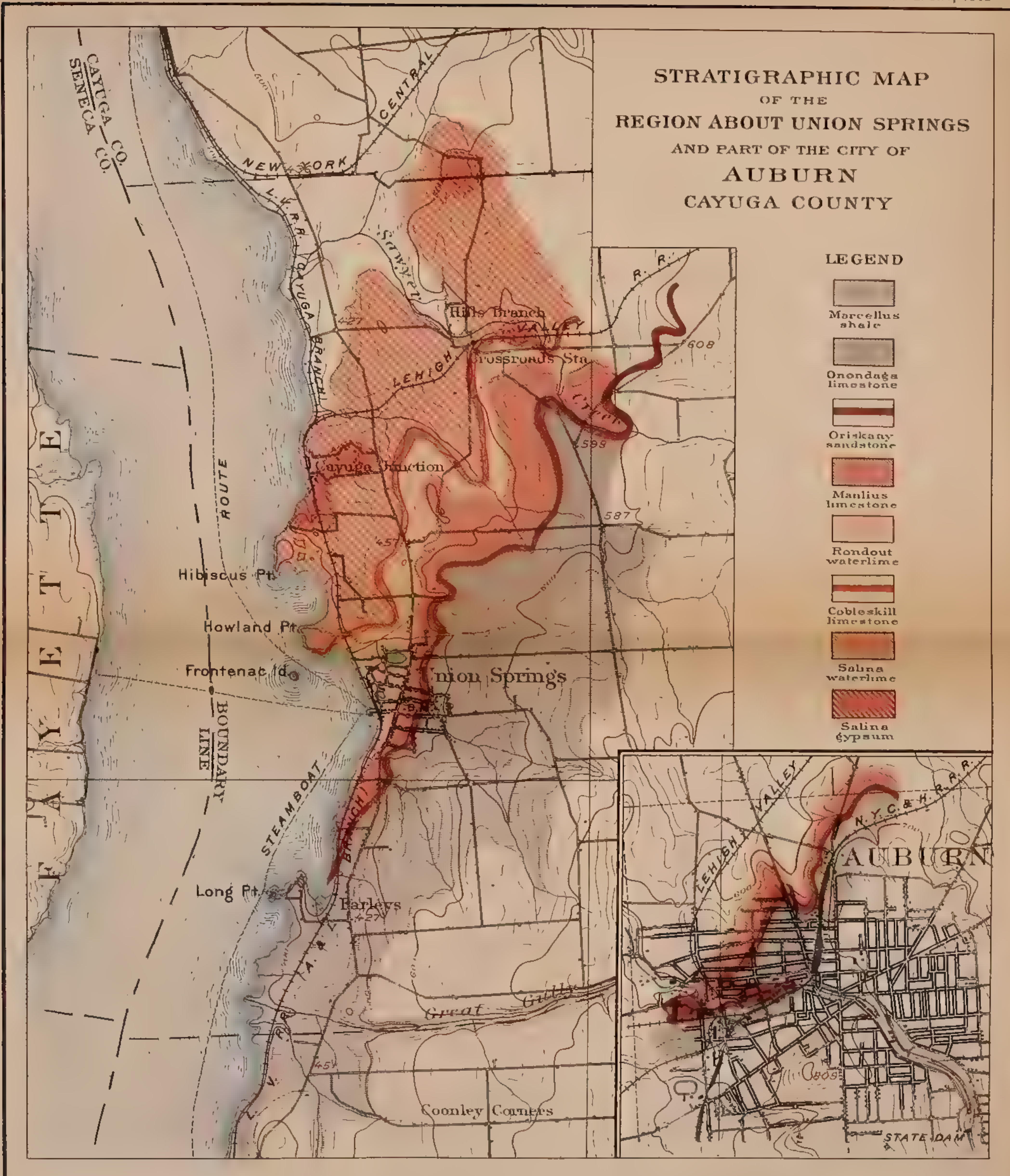
such a pebbly bed may thicken into a locally prominent stratum and become a source of perplexity and possible error in tracing the stratigraphy if no near-by measure to a known horizon were obtainable as a check.

Fucoids. Fucoidal remains in the shape of vertical tubes piercing the sandstone or conglomerate layers of the Salamanca are specially characteristic of that horizon and in its northeastern portion were often used as an aid in its identification, though in all cases of doubt reliance was placed in its invertebrate fauna. Southwestward in Warren county, Pa. while vertical fucoidal remains are still often very prominent in the Salamanca, they also occur at other horizons and hence if they may be used at all in that region as an aid in identification, it must be done only with a recognition of this fact in mind.

COLUMNAR SECTIONS

A few columnar sections selected at considerable intervals over the region are added in order to give some idea of the general stratigraphic succession in the region. They are necessarily generalized somewhat in the representation of thin beds. The concealed intervals are in most cases almost certainly shales but in the sections are left blank. In section C pieces of the Wolf creek were found loose on the surface up to the level indicated by the displaced blocks, and the same thing is true of the Salamanca in section E. The thickness of the two thin limestone layers in the basal part of the Oswayo in section F is much exaggerated. In some cases the interval represented as being red shale consists of red and green shales interbedded in very thin layers. The purple or chocolate colored shale beds of the Chemung are seen in sections B and D. Eastward from B the Salamanca conglomerate lenses out, and in B the Subolean conglomerate — though probably not conglomeritic in this particular section — had been eroded before the deposition of the Olean.

Finally, the writer wishes the conclusions that have been reached as to correlations in McKean and Warren counties to be recognized as ones based on a reconnaissance in a region where such work is beset with many difficulties. It is believed, however, that detailed work will only confirm the conclusions reached.



Geology by J. M. Clarke and D. D. Luther.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 Miles

1 ½ 0 1 2 Kilometers

Contour interval 20 feet.

Datum is mean sea level.

The Argus Co. State Printers

FOSSIL FAUNAS OF THE OLEAN QUADRANGLE

BY CHARLES BUTTS

In pursuance of instructions received from the state paleontologist, the fullest possible collections of fossils were made from nearly every fossil-bearing outcrop on the quadrangle, including 259 stations. The analysis of the fossil faunas thus collected reveals their distribution according to the accompanying lists and seems to warrant the division of the strata into several zones, whose positions in the general stratigraphic succession are exhibited in the following columnar section. A few feet of shale exposed in the deeper valleys near the northern margin of the quadrangle are not shown in the section, as no collections were made from it.

These zones correspond with Mr Glenn's divisions as follows: Zone 2 is the Olean conglomerate, zone 3 is the Oswayo shales and Knapp beds, zone 4 is the limestone layer, zone 5 is the interval between the limestone layer and the top of the Salamanca conglomerate, zone 6 is the Salamanca conglomerate, zone 7 is the interval between the Salamanca and Wolf creek conglomerates, zone 8 is the Wolf creek conglomerate, zone 9 is the interval between the Wolf creek conglomerate and the top of the chocolate shales, zone 10 is the chocolate shales and the quarry sandstones, zone 11 is the interval between the quarry layer and the Cuba sandstone, and zone 12 is the latter bed.

On comparison of the zonal lists, it appears that there is a gradual disappearance of species on passing upward through the strata without the appearance of any new elements till the horizon of the Wolf creek conglomerate is reached. The zones below this horizon are therefore based on this disappearance of species at certain horizons, which gives rise to a slightly different facies to the overlying fauna. The zones do not coincide with the vertical range of some one or more characteristic species having definite upper and lower limits. Thus, so far as my collections show, Orthothetes chemungensis does not pass above the top of no. 11, Athyris angelica disappears at the top of no. 10, while at the top of no. 9 all but nine species disappear, and their places are taken in the next zone, the Wolf creek conglomerate, by new genera and species.

This important faunal change with the incoming of the Wolf creek conglomerate, taken in connection with the fact that on stratigraphic grounds, the equivalent of the Waverly of Ohio, of Subcarbonic age, is pretty certainly present in this quadrangle, and in connection with the fact that the fauna of the conglomerate and higher beds contains a small Subcarbonic element, would indicate that the bed might be provisionally adopted as the base of the Subcarbonic in the quadrangle. Of the 128 species collected, 60 species occur below the Wolf creek conglomerate only, 59 species occur above the same horizon only, and nine are common. Of the 59 species occurring above the conglomerate, seven species can be referred to the Lower Carbonic. These are Ctenodus flabelliformis, Gyracanthus sherwoodi, Oehlertella pleurites, Orthothetes crenistria, Glossites (Sanguinolites) amygdalinus?, Sphenotus aeolus? and Crenipecten winchelli. The stratigraphic significance of the abundant Ptychopteria fauna, so highly characteristic of zones 8 and 7, is not fully understood, as its stratigraphic relationships have not been fully worked out. It must be admitted that the positive evidence is scanty and in itself hardly sufficient to establish a boundary line between the Devonic and Carbonic at the base of the Wolf creek conglomerate, but in a case like this, where the stratigraphic evidence warrants the conclusion that such a boundary line exists, this evidence seems sufficient to give it a provisional location. Further than this it would be hardly safe to go. If this location be not accepted, there seems to be no paleontologic ground for such a boundary line at all below the Olean conglomerate.

Of the remaining zones, no. 5 is almost barren of fossils, no. 4 is a thin limestone in which Camarotoechia allegania Williams, makes its advent. This species is specially abundant in no. 3 and highly characteristic of it. A few fragmentary remains of a Camarotoechia and an obscure pelecypod or two were found in fragments of Olean conglomerate, hitherto supposed to be nonfossiliferous.

The species of fossils found in and below the Wolf creek conglomerate are all marine. The presence of Holoptychius and Bothriolepis scales in no. 7 would indicate fresh or brackish

water deposits, but, in the midst of these, thin layers of ferruginous conglomeritic sandstones or lumpy mud rock bearing marine fossils occur. No fossils of any kind are found in the red shales of no. 7 and 5. The fossils from the top of no. 7 to the top of the section are all marine with the possible exception of some obscure impressions of plant stems, some of which appear to be calamites, occurring at the top of the Olean conglomerate.

The most favorable localities for collecting in zones no. 11 and 12 are found in the quarries and ravines at Cuba and vicinity and near the mouths of streams entering Ischua creek from Hinsdale to Ischua. In the other zones the best exposures occur and the best opportunities for collecting are found in the quarries and railroad cuttings both north and south of Olean. The Wolf creek conglomerate however has yielded fossils only in loose material in the vicinity of Portville on Wolf creek and on the high hills in the northeastern part of Cuba township.

LIST OF SPECIES SHOWING ZONAL DISTRIBUTIONS

DEVONIC

Chemung beds

Zone 12, Cuba sandstone lentil

(base of section)

Spirifer disjunctus *Sowerby*
S. mesacostalis *Hall*
Athyris angelica *Hall*
Camarotoechia contracta *Hall*
Orthis (Schizophoria) impressa *Hall*
Orthothetes chemungensis *Conrad*
Productella lachrymosa *Hall*
Schizodus rhombeus *Hall*
Grammysia communis *Hall*

Zone 11

Spirifer disjunctus *Sowerby*
Athyris angelica *Hall*
A. cora *Hall*
Camarotoechia contracta *Hall*
C. duplicata *Hall*
Chonetes scitulus *Hall*
Orthis (Schizophoria) tioga *Hall*
O. (S.) leonensis *Hall*
Cryptonella *sp.* ?
Orthothetes chemungensis *Conrad*
Productella lachrymosa *Hall*
P. costatula *Hall*
P. onusta *Hall*
P. speciosa *Hall*
Aviculopecten ? *Hall*
A. cancellatus *Hall*
A. rugaestriatus *Hall*
A. *sp.* ?
Crenipecten crenulatus *Hall*
Edmondia subovata *Hall*
E. phillipi *Hall*
E. obliqua *Hall*
Leptodesma potens *Hall*
L. potens *var.* juvens *Hall*
L. mortoni *Hall*
L. sociale *Hall*
L. longispinum ? *Hall*
L. protextum ? *Hall*

L. spinigerum *Hall*?
Lyriopecten *cf.* anomiiformis *Hall*
Macrodon chemungensis *Hall*
Modiomorpha quadrula ? *Hall*
Nucula *cf.* bellistriata *Hall*
Palaeoneilo brevis *Hall*
Pterinopecten crenicostatus *Hall*
P. neptunus *Hall*
Sphenotus clavulus *Hall*
S. *sp.* ?
Grammysia subarcuata *Hall*
Orthoceras *sp.* ?
Cyclonema *sp.* ?
Euomphalus hecale *Hall*
Macrochilus *sp.* ?
Dictyospongia *sp.* ?

Zone 10

Spirifer disjunctus *Sowerby*
Athyris angelica *Hall*
Camarotoechia contracta *Hall*
Chonetes scitulus *Hall*
Lingula *sp.* ?
Orthis (Schizophoria) leonensis *Hall*
O. (S.) tioga *Hall*
Productella lachrymosa *Hall*
Aviculopecten tenuis *Hall*
A. duplicatus ? *Hall*
A. *sp.* ?
Crenipecten crenulatus *Hall*
Edmondia phillipi *Hall*
Leptodesma potens *Hall*
L. potens *var.* juvens *Hall*
L. mortoni *Hall*
L. sociale *Hall*
Mytilarca chemungensis (*Conrad*) *Hall*
Nucula ?
Pteronites ?
Ptychopteria ?
Pterinopecten crenicostatus *Hall*
P. neptunus *Hall*
Schizodus *sp.*
Sphenotus clavulus *Hall*
S. contractus *Hall*
S. *sp.* ?
S. *sp.* ?
Grammysia subarcuata *Hall*
Orthoceras *sp.* ?
Bellerophon maera *Hall*
Cyclonema ?
Euomphalus hecale *Hall*
Straparollus *sp.* ?
Prismodictya choanea *Hall & Clarke*
P. prismatica *Hall*
Thysanodictya poecilus? *Hall & Clarke*
T. edwin-halli *Hall & Clarke*

Zone 9

Spirifer disjunctus *Sowerby*
Camarotoechia contracta *Hall*
C. contracta *var.* robusta *Butts*
C. sappho ?
Chonetes scitulus *Hall*
Orthis (Schizophoria) tioga *Hall*
Productella lachrymosa *Hall*
Aviculopecten *sp.* ?
Edmondia subovata *Hall*
Leptodesma potens *Hall*
L. mortoni *Hall*
L. sociale *Hall*
L. *sp.* ?
Modiomorpha quadrula *Hall*
Nucula ?
Ptychopteria elongata *Hall*
Spathella ?
Sphenotus clavulus *Hall*
S. contractus *Hall*
S. *sp.* ?
Straparollus *sp.* ?
Arenicolites

DEVONO-CARBONIC

Cattaraugus formation

Zone 8, Wolf creek conglomerate lentil

Spirifer disjunctus *Sowerby*
Camarotoechia contracta *Hall*
Lingula
Leptodesma orodes *Hall*
Modiola praecedens *Hall*

P. proto *Hall*
P. salamanca *Hall*
P. elongata *Hall*
Palaeanatina typa *Hall*
Schizodus *sp.* ?
Sphenotus clavulus *Hall*
Gomphoceras *sp.* ?
Orthoceras *sp.* ?

Zone 7

Spirifer disjunctus *Sowerby*
Camarotoechia contracta *Hall*
Lingula *sp.* ?
Oehlertella pleurites *Meek*
Orthothetes crenistria ? *Phillips*
Aviculopecten patulus *Hall*
Leptodesma *sp.* ?
Modiola praecedens *Hall*
Ptychopteria *sp.* ?
P. proto *Hall*
P. salamanca *Hall*
P. *sp.* ?
P. elongata ? *Hall*
Palaeanatina typa *Hall*
P. solenoides *Hall*
Schizodus rhombeus ? *Hall*
Sphenotus clavulus *Hall*
S. *cf.* arcuatus *Hall*
Grammysia *sp.* ?
Orthoceras *sp.* ?
Bellerophon *sp* ?
Straparollus *sp.* ?
Tropidocyclus ?
Strophostylus ?
Bothriolepis minor ?
B. *sp.* ?
Ctenodus flabelliformis *Newberry*
Holoptychius americanus
Gyracanthus sherwoodi *Newberry*

Zone 6, Salamanca conglomerate lentil

Spirifer disjunctus *Sowerby*
Camarotoechia contracta *Hall*
C. sappho *Hall*
Crenipecten winchelli *Meek*
Leptodesma orodes *Hall*
L. curvatum *Hall*
L. macluri *Hall*
L. *sp.* ?
Modiola praecedens *Hall*
Pararca transversa *Hall*
P. elliptica *Hall*
P. transversa *Hall*
Allerisma ? *n. sp.*
Ptychopteria proto *Hall*
P. salamanca *Hall*
P. *sp.* ?
P. elongata ? *Hall*
Palaeanatina typa *Hall*
Schizodus chemungensis *var.* quadrangularis *Hall*
S. *sp.*
Sphenotus aeolus *Hall*
Orthoceras *sp.* ?
Straparollus *sp.* ?

Zone 5

Ptychopteria perlata ? *Hall*
Pterinopecten suborbicularis ? *Hall*
Sphenotus clavulus *Hall*
S. contractus *Hall*
Orthoceras *sp.* ?
Agelacrinites buttsi *Clarke*

SUBCARBONIC

Oswayo formation

Zone 4, limestone lentil

disjunctus *Sowerby*
Camarotoechia allegania *Williams*

Zone 3, Oswayo shales and Knapp beds

Pugnax ? *sp.* ?
Lingula *sp.* ?
Syringothyris randalli *Simpson*
Rhynchospira scania *Hall & Clarke*
Bryozoan *gen. and sp.* ?
Spirifer disjunctus *Sowerby*
Athyris polita *Hall*
Camarotoechia allegania *Williams*
C. sappho *Hall*
Oehlertella pleurites *Meek*
Orthothetes *cf.* crenistria *Phillips*
Aviculopecten ?
A. *sp.* ?
Pararca transversa *Hall*
Mytilarca simplex *Hall*
Grammysia *cf.* hannibalensis *Shumard*
Allerisma ? 2, *sp. nov.* ?
Palaeanatina typa *Hall*
Schizodus chemungensis ? *Hall*
Orthoceras *sp.?*
Leptodesma orodes *Hall*
L. curvatum *Hall*
L. maclurii *Hall*
L. *sp.* ?
L. mytiliforme
Liopteria *sp.* ?
Ptychopteria *sp.* ?

CARBONIC

Zone 2, Olean conglomerate

Camarotoechia *cf.* allegania *Williams*
Ptychopteria ?
Sphenotus contractus ?

CONSTRUCTION OF THE OLEAN ROCK SECTION

BY JOHN M. CLARKE

The differing interpretations of the Olean section given by Professor Glenn and Mr Butts in the papers preceding, afford an excellent illustration of the discrepancy which often results from the two modes employed. This discrepancy pertains however solely to the determination of a conventional boundary plane in sediments characterized by the uniformity of their succession. The sequence of events involves the independent construction of the lithologic or purely stratigraphic evidence and of the facts derived from the succession of faunas. In a great thickness of arenaceous sediments carrying variable intermixture of clay, slight and oft recurring differences of texture are produced and these variations are so locally related to coastal contour and bathymetry, to tidal ebb and flow and to stream discharge, that sedimentary differences seldom hold true far away from a given section. In the Upper Devonic of New York this marine arenaceous sedimentation prevails through a thickness of 2500 to 3000 feet. It has long been a subject of close study. By the construction of a large number of meridional sections from east to west through the lower or Portage division of this sedimentation we believe that we have now arrived at an understanding of the proper correlation of sections which, in the actual succession of sediments, differ fundamentally. Doubtless with the similarly close analysis of the Chemung beds we shall arrive at an equally clear understanding of the succession and lateral extension of sedimentary differences. If we have gained any lesson from the careful analysis of these earlier or Portage sediments and their contents it is this, that in these shallow water deposits there is very little correspondence between the sediments and the organisms that lived on them, that indubitably continuous sediments may carry, without necessary variation of texture, wholly different organic combinations at different places; that faunas shift, encroach on the provinces of others and retreat without concomitant change in the sedimentation. Hence a history of the events of sedimentation from which may be drawn the record of coastal alterations, of shifting coast lines and bars, and, in consequence of increased or lessened terrestrial

erosion, does not correspond with exactitude to the succession of events recorded by the dissemination of faunas and their internal changes of composition.

Perhaps no more effective illustration of the discrepancy in these standards of classification could be brought forward than that of the Portage sandstone, an element in this series of arenaceous deposits — a well marked stratum which at the east of this region contains a highly developed Chemung fauna, but westward carries no Chemung species whatever and still farther west changes its lithologic texture also. Some hundreds of feet of sediment under it in the east likewise carry a brachiopod fauna, while in the west that fauna is wholly replaced in equivalent and continuous strata. We could not therefore portray on a map the succession of faunas for the Portage or lower belt of these arenaceous strata, so that there would be any correspondence to a cartographic portrayal of the succession of sediments.

So far as we now understand the Olean and Salamanca regions after the careful survey on which Professor Glenn has reported and from a long standing previous acquaintance with the rocks and their contents, it may be said that there is less probability of discrepancy in the deductions derivable from independent consideration of the stratigraphic and the paleontologic evidence because the uniformity of sedimentation is unaccompanied by so pronounced differences in faunation.

The most serious question involved in this survey so far as concerns the classification of the rock formations, is the construction of the Cattaraugus beds, the mass of chiefly red shales and sands with their included conglomerate lenses. To indicate the transitional character of these beds by employing as a provisional designation *Devono-Carbonic,* as was at one time suggested, is on the whole a makeshift satisfactory to no one. Hence Professor Glenn has preferred to admit them, for the time being, into the Devonic and to place the line of division between that and the Carbonic system at the top of these red Cattaraugus beds.

It seems important however to take note of the two considerations through which this provisional determination is reached: (1) a possible unconformity at the top of the Cattaraugus beds, (2) the assumption of continuity of these red beds with the

Catskill sediments of eastern New York and the tacit concession of the Devonic age of the entire series of those deposits. With regard to the phenomena interpreted as evidence of unconformity I should not be disposed to contest Professor Glenn's inferences but to emphasize the fact that these sand reefs constantly display indications of deep decapitation due to shifting of bars and change of direction of currents, or a modification by heavy tidal flow on a shelving coast. Unconformities thus frequently exist which are no indication of unrecorded time. As to the second assumption I feel that we should be specially cautious in taking for proven that Catskill sedimentation even in the typical section of the Catskill mountains is restricted to Devonic time. The Catskill represents a peculiar phase of sedimentation widespread in northern latitudes during the Devonic. The Devonic continent was profuse in great lakes and coastal lagoons whose sedimentation was carried on under conditions so unlike those of the ocean, that causes which would disturb and qualify the latter could not affect the former. We know that at certain places within the continental edge this sedimentation did continue through the Devonic and endured till after the appearance of Carbonic faunas. Hence a certain part of Old Red sedimentation is in some instances postdevonic and may be so in New York; indeed in face of the paleontologic evidence I am very strongly of the conviction that it is so, and that the Cattaraugus beds themselves supply the required proof of this fact. It is not a new suggestion that the upper stages of the typical Catskill are postdevonic; the restudy of this Catskill area which is now proceeding may give us new light on this point and though it would be the unexpected to find transgression of the Subcarbonic fauna extending into this lagoon area so far to the east, by some other criteria it may be practicable to affirm this distinction. Time must also elapse before assertions can be made as to whether the Catskill strata of eastern New York are or any part of them is continuous with the Cattaraugus beds of Allegany and Cattaraugus counties.

The paleontologic evidence thus far derived from this section and summarized by Mr Butts, indicates one fact with emphasis, that is, the one substantial change in the succession of organic assemblages occurs with the incoming of the Wolf Creek con-

glomerate, at the base of the Cattaraugus beds. Here Carbonic types appear, a new fauna is introduced and without attempting to analyze again the time values of the various components (I have already discussed this point in my report of last year, *op. cit.* p. 524) it is enough to add that while the withdrawal of a large part of the Devonic fauna is concurrent with this new arrival, it is altogether to be expected that certain Devonic types survive. It will not do to state this condition as merely an intermixture of Carbonic and Devonic organisms, a characterization easily made and which would dismiss these beds as "transitional" but it is rather the fact of a new arrival in the field while survivors of the old faunas or superstitial species still endure. The condition is normal for the process of replacement of one fauna by another. It matters little if among the superstitial species one remains so characteristic everywhere of the later Devonic as Spirifer disjunctus; for not alone in New York does this species transcend the limit of the Devonic and enter the Carbonic. With proper regard for such modifications as additional evidence may require I am disposed to the conviction that in placing the dividing line between Devonic and Carbonic at the base of the Cattaraugus beds, as is done on the geologic map, we have the support of the most direct evidence.

STRATIGRAPHY OF PORTAGE FORMATION BETWEEN THE GENESEE VALLEY AND LAKE ERIE

BY D. DANA LUTHER

With stratigraphic map

Genesee valley

The Portage formation received its name "from its superior development along the banks of the Genesee river in the district formerly included in the town of Nunda, now Portage," Livingston co.[1] The Genesee river is a northward-flowing stream, rising just over the Pennsylvania line and completely traversing the State to Lake Ontario.

About 2½ miles south of the north line of this town the valley through which the river has flowed northward for 50 miles or more, ends, and the stream between vertical cliffs 200 feet in hight enters a narrow rock gorge, plunges over three cascades respectively 76 feet, 110 feet and 66 feet high, with rapids above, below and between them, and descends about 350 feet in 2 miles, and 30 feet more to the north line of Portage township; so that, including 187 feet of sandstone above the river at the upper end of the gorge and 75 feet for the southward dip, about 635 feet of strata are exposed in the district referred to.

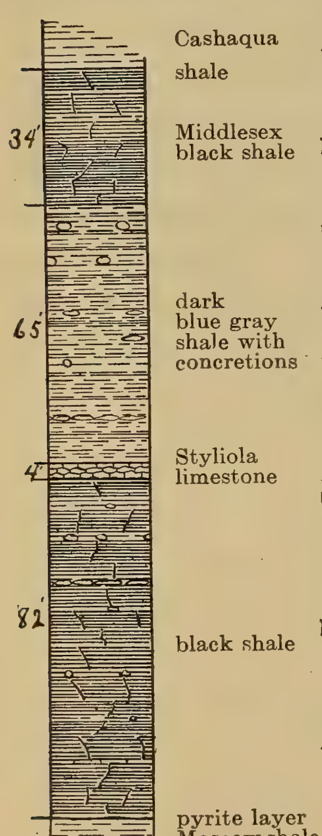


FIG. 1 The Genesee shale at Moscow to top of Styliola limestone and at Mt Morris to the Cashaqua shales

The course of the river across the next town north, Mount Morris, is through a narrow canyon that broadens out to a valley ¼ to ½ mile wide, with steep banks and vertical cliffs from 100 feet to 250 feet high, and is about 6 miles long; this is followed northward by another canyon with vertical cliffs, 150 feet to 300 feet high, on both sides, in which the river dashes from side to side till the mouth of the gorge is reached at the village of Mount Morris, 11 miles in a straight line, and about 15 miles if the course of the river channel is fol-

[1] Hall. Geol. N. Y. 4th Dist. 1843.

lowed, from the point where it crosses the Portage town line. In this distance the river descends 100 feet, and the southward dip of the strata is 32.5 feet a mile.

The Portage town line is 9 miles south of the mouth of the gorge at Mount Morris, and the dip therefore adds 292 feet to the thickness of the exposed strata and gives a total of 392 feet, of which all but 65 feet are included in the "Portage group" as described and limited by Prof. Hall.

The Styliola or Genundewa limestone of the Genesee shales, which is 82 feet above the top of the Hamilton shales in the ravine of Little Beards creek at Leicester, 3 miles north of the mouth of the gorge, is exposed in the banks near the west end of the Western New York and Pennsylvania Railroad bridge at Mount Morris, and, with a few feet of black slates below it, is the lowest rock exposure on this section of the river.

About 65 feet of typical upper Genesee shales overlie the Styliola limestone and are exposed at the east end of the covered highway bridge at the mouth of the gorge, where the spheric concretions and characteristic fossils of this horizon are common.

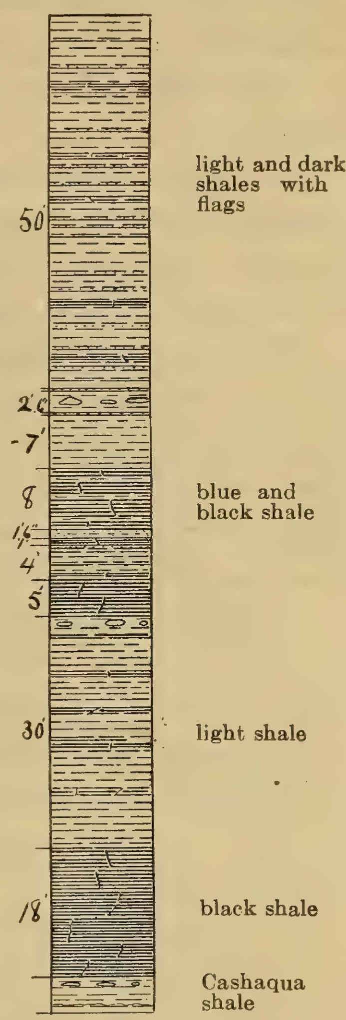


Fig. 2 Section in Buck run ravine at Mt. Morris, above Cashaqua shale. Stations 4, 5

At the top of these bluish black shales there are a few lighter colored layers, some clayey, others slightly arenaceous, distributed through about 3 feet of darker shales. At this horizon a lighter band, hardly noticeable here, but fully developed farther east, has the sedimentary characteristics of the Portage shales and flags and contains a few fossils from both the Genesee and the Portage faunas.

Overlying these passage beds there are 32 feet of densely black and bituminous slaty shales in which plant remains are

common, and a few fish scales and plates have been found, but otherwise they are generally barren. A few small Lingulas (L. spatulata, L. ligea) found at the mouth of Pike creek on Lake Erie are the only fossils collected from this horizon, and they seem to belong to the species found in similar black shales higher in the formation.

This bed of black shales has quite the same structure and appearance as other black bands in the Portage section.

Above this horizon there is no recurrence of the Genesee fauna.

The bottom of the passage beds immediately below the black band is therefore taken as the base of the Portage formation, and the stratum of black shales above has been designated by the state paleontologist as the Middlesex shales.

Middlesex black shales. This bed decreases slightly in thickness toward the west, but is thicker and quite arenaceous in the Dansville and Naples valleys. It is exposed in the cliffs on both sides of the Genesee river, from the mouth southward for a little more than two miles, the dip bringing it down to the water level on the south side of the "Hogsback."

Near the top, after several alternations with lighter layers in a few feet, these shales are replaced by light bluish gray, and olive shales, "soft argillaceous rock of a green color" (Hall).

Cashaqua shales. This mass is 165 feet thick, and was termed by Hall the Cashaqua shales because of their excellent exposure in detail in the gorge of Cashaqua creek, 5 miles east of the Genesee river.

The general color of this shale in weathered exposures is a very light olive; but, when freshly excavated, it is medium dark bluish gray with frequent intercalations of darker or black layers of varying thickness, sometimes so thin and frequent as to give the rock a straticulate or laminated structure.

In the section along Cashaqua creek there are a few thin flags in this horizon, and they increase in number toward the east. They are hardly noticeable in the Genesee river section.

Uneven concretionary and more or less calcareous layers from 1 inch to 4 inches thick occur frequently, and some of them are continuous for many rods. Spheric and elongated concre-

tions from 1 inch to 1 foot in diameter are common throughout the mass, and appear in the rock wall at some horizons in well defined rows.

Fossils are not abundant in any part of these shales, but a few specimens occur in the lower part; they are much more common in the upper part, where they are found in considerable numbers in a few thin layers of shale and also in the concretionary layers and the separate concretions.

A row of concretions, usually a foot or more in diameter at the top of these shales and exposed in the river section, rests on a calcareous layer ½ inch to 2 inches thick that is composed of fossils, many of which are finely preserved. This row of concretions is found at this horizon in nearly all the exposures of the shales from the Bristol valley, Ontario county on the east, to the Tonawanda valley, Wyoming county on the west.

It is exposed in the cliffs along the Genesee river for about 3 miles and comes down to the water level at the north end of Smoky hollow.

The passage from the Cashaqua shales to the next succeeding formation is through alternations of light and dark shales, like those below, and the line of separation is therefore an arbitrary one.

In the thickness given, 165 feet, nearly all of the transition layers at the top and bottom are included. Like the Hamilton, Genesee and the Middlesex shales, the Cashaqua shales thin toward the west, their thickness in the Lake Erie section being only 32 feet. In the Naples section farther east (Ontario county) there are 237 feet of shales and thin sandstones in this subdivision of the Portage formation.

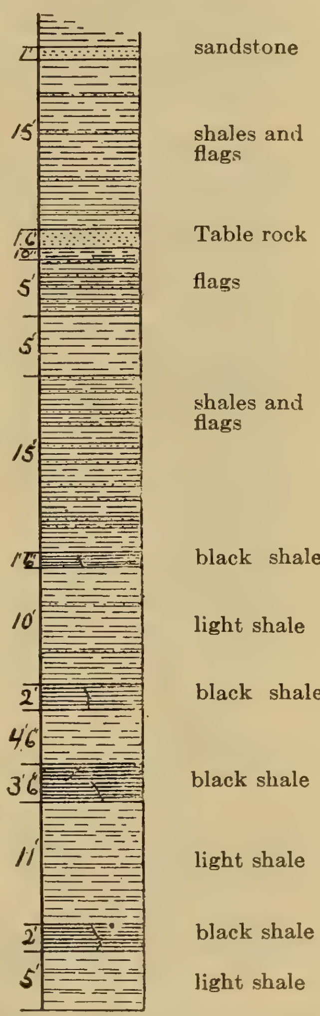


Fig. 3 Section at Lower Portage falls. Station 9

Alternate layers of black and gray shale overlie the fossiliferous concretions at the top of the Cashaqua beds to the thickness

of 5 feet and are succeeded by 18 feet of black shale and 30 feet of dark and light shales in thin layers.

Rhinestreet black shales. As the lighter shales decompose more rapidly than the black, the latter predominate in the coloring and, specially in old exposures, give to this division the appearance of being a homogenous bed of black shale. The division has therefore been termed the Rhinestreet black shale from an exposure in the town of Naples.

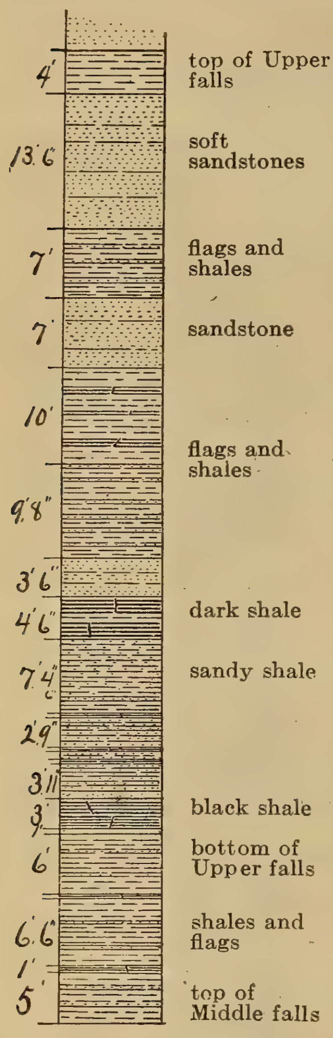


FIG. 4 Section from top of Middle Portage falls to abutments of bridge above the Upper falls. Stations 10, 11

It is continuous from Yates county to Lake Erie, and, unlike all of the formations below it down to the Onondaga limestone it increases in thickness toward the west.

It is 20 feet thick in the Naples section, 58 feet in the Genesee river cliffs and 185 feet in the Lake Erie section.

Fossils are exceedingly rare in these black layers except terrestrial plant remains, which are found occasionally, drifted together and forming small thin layers of impure coal. Fish remains have been found in this horizon at Sparta, Livingston co., and other localities toward the east, and a few specimens of Lingula and an abundance of conodont teeth have been obtained from it.

This bed is exposed in the cliffs on the east side of Smoky hollow and at the falls in the outlet of Silver lake at Gibsonville, also at the cascade in Buck run and on Cashaqua creek at Tuscarora. It is the base of "the great development of green and black slaty and sandy shales with thin layers of sandstone" between the Cashaqua shales and the Portage sandstones to which Professor Hall gave the name of "Gardeau shale and flagstones."

The latter include 661 feet of strata exposed along that part of the river formerly in the Gardeau Indian reservation and to the top of the Upper falls at Portageville.

Hatch flags and sands. Above the Rhinestreet shales are light and dark shales, 88 feet, in layers of varying thickness from a fraction of an inch to several feet, and with a few thin flags of fine blue sandstone distributed at irregular intervals. A row of symmetric concretions, from 1 foot to 1½ feet in diameter lies at the base of this subdivision, and many others of various sizes and shapes are scattered through it and serve to distinguish it from the overlying beds. Fossils are rare except in a few of the lighter layers, but the beds are more fossiliferous toward the east.

Above there is a band of flaggy sandstones, 6 feet thick, exposed for several miles in the cliffs on the east side of Smoky hollow and the Gardeau flats. It comes down to the river level opposite the "Five Corners road," 1 mile north of St Helena. At this point the cliff above the flaggy band shows 115 feet of shale in which no sandstones appear except about 10 feet of thin flags. A large proportion of this shale is dark and slaty, and the remainder is quite ferriferous, consequently the general aspect of the weathered face is very dark, almost black, and rusty. Fossils are almost entirely absent.

In the escarpment at the east end of the St Helena bridge 60 feet of these shales are exposed and are overlain by 25 feet of flags and soft sandstones that are separated from each other by thin layers of hard blue shale.

This arenaceous bed is thicker and proportionately sandier toward the east. In the Dansville, Springwater and the Naples valleys it contains fossil sponges, and at the last place many brachiopods and other fossils, and marks the upper limit of the normal Portage fauna, and is there known as the Grimes sandstone.

At the mouth of Wolf creek this bed is overlain by shales and flags 110 feet thick, in which dark or black shales still predominate. It is exposed in the rock wall beneath the "Table rock" above the mouth of Wolf creek near the south road from St Helena to Castile, and in the gorge southward between the

"Twin Hogsbacks" to the Lower falls. It is seen also in the lower part of the Wolf creek ravine.

Fossils are very rare in it, but a few of the common Portage forms occur in the soft shales.

Gardeau shales and flags. The layer of compact blue sandstone, 1 foot, 3 inches thick, that forms the "Table rock" at the mouth of Wolf creek ravine, is the same stratum as the "Table rock" at the crest of the Lower Portage on the Genesee river.

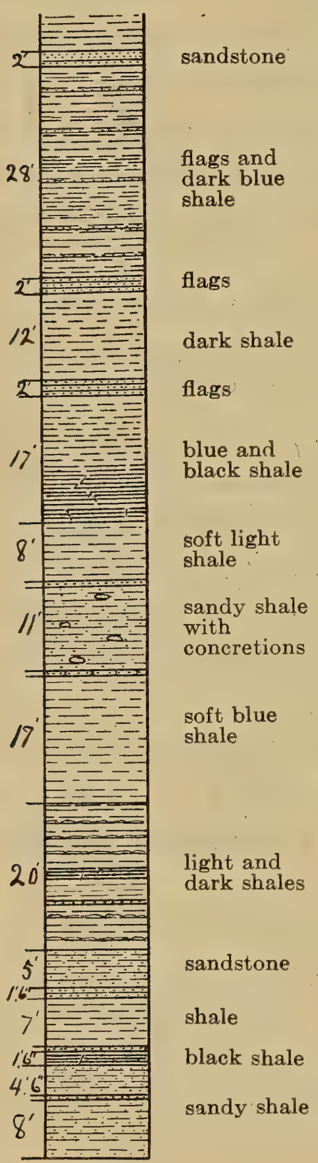


Fig. 5 Section in the ravine at Wiscoy. Station 15

Above this mass lie 15 feet of soft light and dark shales and thin flags, at the top of which is the hard even sandstone, 12 inches thick, that forms the crest of the low cascade at the head of the Flume. Fossils are quite common in the soft light shales between the two sandstone layers.

There are 49 feet of strata, mostly shales, between "Table rock" and the horizon of the bottom of the Middle falls, and 113 feet in the face of the Middle falls, in which there is a much larger proportion of sandy layers.

Fallen blocks of the sandstones from the vertical cliffs at and below the falls are almost entirely barren, but Aulopora and a few brachiopods, of species common in this horizon farther east, were found, but these probably came from some of the sandy layers above.

There are 19 feet of flags and shales exposed between the top of the Middle and the horizon of the bottom of the Upper falls.

Fossils are quite common in a few of the soft layers of shale or shaly sandstone exposed between the Middle and Upper falls and to the base of the heavy sandstones above the Upper falls. They all belong to the Portage fauna, no brachiopods

being found among them. In the face of the Upper falls are 77 feet of flags and shales, and a layer of rather hard blue shale 4 feet thick exposed in the river bed for a few rods above the falls is taken as the top of the Gardeau shales and flags.

In the 262 feet of strata between the "Table rock" and the top of the Gardeau beds, changes in the sedimentation are very frequent. Layers of black, blue black, blue gray and olive shales, and blue or olive sandstone, usually but a few inches thick, succeed each other in irregular order, but there is a noticeable increase upward in the sandy layers, and in the face of the Upper falls they equal or exceed the shales, though there are no heavy compact layers.

Portage sandstones. The Portage sandstones consist of 187 feet of strata exposed in the walls of the gorge above the Upper falls, from the top of the 4 foot shaly layer at the crest to the top of the cliff on the east side south of the high railroad bridge.

Except a bed of hard blue shale, containing calcareous nodules, 2 feet thick, 12 feet above the base and a layer of similar character 6 feet thick and 52 feet higher, the entire formation is composed of light bluish gray sandstone in layers from 2 feet to 10 feet thick, separated by ½ inch to 6 inches of shaly matter.

In some of the upper layers the sandstone is compact, durable and valuable for building purposes. Other layers are schistose along the laminae, and a few are shaly and friable. Large obscurely defined concretions occur in one or two of the more calcareous layers, but they are few.

The two beds of shales and the shaly partings between the layers contain a very few fossils, all like those below.

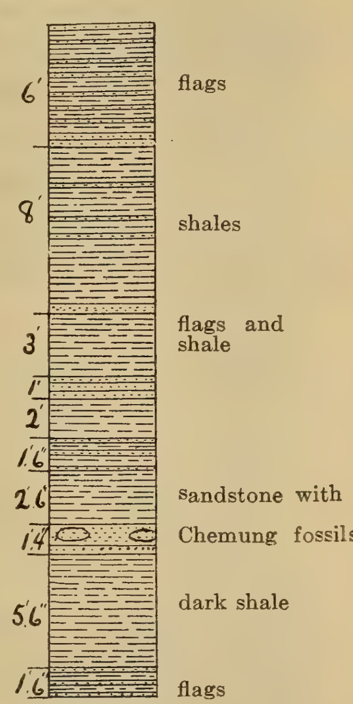


FIG. 6 Section at Long Beards riffs. Station 13

In the sandstones Fucoides verticalis is common, and plant remains occur, but otherwise they are practically barren here and along Wolf creek below

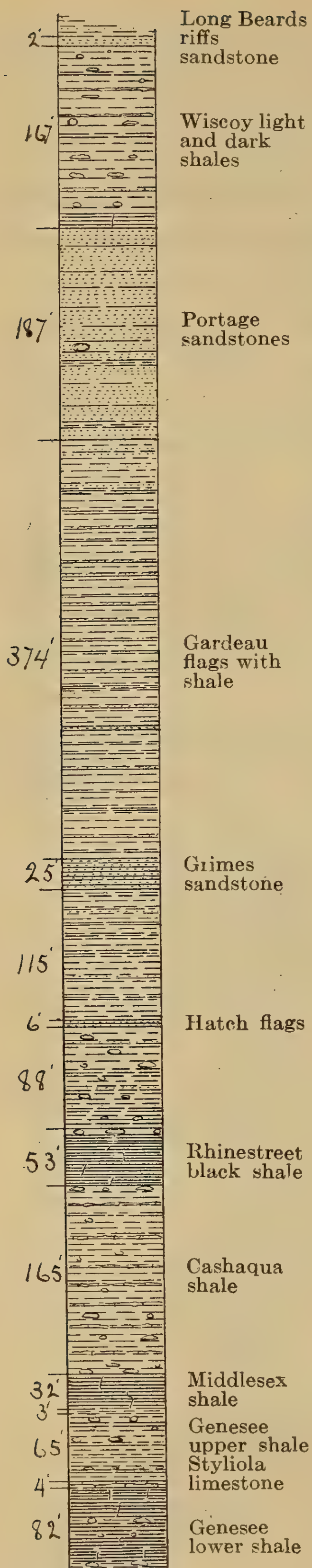


Fig. 7 Section on Genesee river from top of Hamilton at Moscow to Chemung sandstone at Long Beards riffs, near Fillmore. Stations 0 to 15

Castile. They are exposed near the reservoir on Quarry hill 1 mile south of Nunda, and a thin seam contains comminuted crinoids and brachiopod shells.

In the Dansville and Naples sections these beds contain an abundant Chemung fauna.

There is a small exposure of the sandstones on the west side of the valley 1½ miles south of Portageville, and the compact upper layers are quarried by the Genesee Blue Stone Co. 1 mile farther south.

The contact line between the sandstones and the succeeding formation is covered by drift in the immediate vicinity of the river, but a bed of black shales is exposed at Hunts Station on the east and 2 miles west from the high Portage bridge and along Wolf creek near Hopkins mill at Castile, the position of which is such as to show that the section exposed at Portageville practically includes all of the "Portage sandstones."

Wiscoy shales. The fossiliferous layers are exposed in the north bank of the ravine of Wiscoy creek ¼ mile above the village of Wiscoy, and below it are 137 feet of strata, many layers of which are black shales and others are soft, light colored and clayey.

Small calcareous concretions are common; and, except for the presence of a few thin sandstones, the entire formation between the Portage sandstones below and the Long Beards riffs fossiliferous layer, so far as it is exposed, bears a close resemblance to the Cashaqua shales, and the fossils bear a much closer relationship to the Portage fauna than to that of the Chemung rocks.

The Wiscoy shales are also exposed in Scotts ravine 2 miles northeast of Fillmore and in several other ravines on the east side of the valley opposite Rossburg.

Naylor's quarry near the Erie Railroad station at Castile shows a small section in the Wiscoy shales in which Manticoceras rhynchostoma is common at one horizon in the soft sandy shale.

Toward the east the Wiscoy shales are more arenaceous, and the horizon is one of laminated or flaggy olive sandstones in which Chemung brachiopods are abundant.

Long Beards riffs sandstone. There are no rock exposures along the river between the Genesee Bluestone Co.'s quarries and Long Beards riffs, ½ mile south of Fillmore, a distance of about 8 miles.

At this point an uneven layer of hard calcareous sandstone makes a low cascade in the river and is exposed on both sides of the channel.

An escarpment on the east side of the riffs shows 10 feet of shales and flags below the principal layer, and 3.5 feet of shales with a few even layers of sandstone above it.

This heavy layer and another 4 inches thick 25 feet higher contain Chemung brachiopods abundantly.

This horizon is the lowest in which Chemung brachiopods were found in place in the Genesee river section.

Estimates based on such measurements as could be made, show it to be about 167 feet above the top of the "Portage sandstones" as exposed at Portageville.

Résumé

The Portage group, as exposed in the gorge of the Genesee river, which is the type section, includes between the top of the shales bearing a distinctively Genesee fauna at the mouth of the gorge and the top of the Wiscoy shales at Long Beards riffs, 1207 feet of strata.

Marked changes in the character of the sedimentation make the following subdivisions of these beds recognizable, beginning at the base of the section:

		Thickness in feet
1	Passage shales	3
2	Middlesex black shale	32
3	Cashaqua shale	165
4	Rhinestreet black shale	53
5	Hatch shale	203
6	Grimes sandstone	25
7	Gardeau shales and flags	372
8	Portage sandstones	187
9	Wiscoy shale	167
	Total	1207

The following stations are localities where exposures of these rocks are favorable for study.

1 Mouth of the gorge at Mount Morris. Formations exposed: the Styliola limestone, Upper Genesee shales, the transition bed and the Middlesex shales of the Portage group.

2 1½ miles south of the mouth of the gorge. The Middlesex shale and the base of the Cashaqua shale.

3 Lower part of the Buck run ravine, ½ mile east of Mount Morris. The Cashaqua shale.

4 Upper part of the Buck run ravine. The Rhinestreet and the Hatch shales.

5 North end of Smoky hollow, opposite the mouth of the Silver lake outlet. The Cashaqua, the Rhinestreet shales, and the Hatch shales and flags.

6 Cliffs opposite the "Five Corners road" 1 mile north of St Helena. The Hatch flags.

7 East end of bridge at St Helena. The Hatch flags and the Grimes sandstone.

8 Cliffs and ravine at the mouth of Wolf creek. The Grimes sandstones, Gardeau shales and flags.

9 Top of Lower falls. The Gardeau flags and shales.

10 Top of Middle falls. The Gardeau flags and shales.

11 Foot of Upper falls. The Gardeau beds.

12 Sides of the gorge above the Upper falls. The Portage sandstones.

13 Long Beards riffs, 1 mile south of Fillmore. Lowest sandstones with Chemung fossils.

15 Wiscoy creek ravine, above the bridge at Wiscoy. The Wiscoy shales, the Long Beards riffs sandstones and Chemung shales and sandstones.

20 Wolf creek ravine below Castile. The Portage sandstones and the lower part of the Wiscoy shales.

42 The ravine of Cashaqua creek from Son Yea to Tuscarora. The Cashaqua and Rhinestreet shales.

Oatka valley section

That part of the Oatka creek, or Warsaw valley, in which the bed rock belongs to the Portage formations, lies about 10 miles north and west, and 300 to 400 feet higher than the exposures of the same horizons in the Genesee river section, and is about 13 miles long.

The Portage sandstones and the top of the Gardeau flags are exposed at Oatka falls near Rock Glen, but there are no other exposures of Portage strata in the channel of the river. There are many ravines, some of which are very deep, in the sides of the valley, and they afford good exposures, that together, virtually cover the entire Portage section.

The following are some of the most important of the exposures, beginning at the north.

In a small ravine on the west side, about opposite the village of Pearl Creek, the little brook flows over a cascade 15 feet high, of which a compact layer of the Styliola limestone of the Genesee shales forms the crest.

Above the cascade about 50 feet of bluish upper Genesee shales are exposed, and a few feet of the Middlesex shales of the Portage formation outcrop above them, and rest directly on the Genesee shales.

The transition bed is not perceptible here.

In the ravine at Wyoming village about 50 feet of the upper part of the Cashaqua shales are exposed. They are mostly light bluish gray or olive and very soft. Calcareous concretions and concretionary layers are frequent. Fossils are quite common.

Farther up the ravine and about ¼ mile from the village, 40 feet of black shales in the horizon of the Rhinestreet shales are exposed, and above them, about 30 feet of alternate layers of light and dark or black shales.

The upper Cashaqua beds are also exposed along a small brook that comes into the valley on the east side ½ mile south of the Wyoming railroad station.

In a ravine on the west side of the valley, 2 miles south of Wyoming, 150 feet of the Hatch shales are exposed, and in another ravine about 2 miles farther south 120 feet of the strata next higher in the section.

A flaggy band that occurs near the top of the exposure in the latter ravine is probably in the horizon of the Grimes sandstones, but it is proportionately less arenaceous.

In the Fall brook ravine ½ mile southwest of Warsaw there are 236 feet of shales and flags exposed below the Erie Railroad bridge. They are all in the horizon of the middle portion of the Gardeau beds, or that of the Lower and Middle falls at Portageville.

Gibson's glen is a ravine on the west side of the valley 2½ miles south of Warsaw, that ends in a high fall, above which the basal layers of the Portage sandstones outcrop. About 150 feet of flags and shales are exposed below the sandstones. A thin layer of soft shale at the mouth of the glen contains many flattened concretions, in some of which finely preserved fossils occur.

A few fossils occur in all parts of the Gardeau division in this valley, but they are much more common near the bottom and toward the top than in the middle of it.

In the ravine of Oatka creek, at and below the falls near Rock Glen, about 100 feet of Gardeau flags and shales are exposed and the lower layers of the Portage sandstones outcrop along the stream above the falls.

The old quarries of the Warsaw Bluestone Co. on the west side of the Erie Railroad, near the village of Rock Glen, show about 50 feet of the lower part of the Portage sandstones, and the upper part outcrops along the little brook southwest of the quarries.

Stations in the Oatka valley

47 Ravine on west side opposite Pearl Creek. Exposed: lower Genesee shales, the Styliola limestone, the Upper Genesee shales and the Middlesex shale of the Portage group.

48 Ravine on west side at Wyoming. The Cashaqua shales and the Rhinestreet shales.

49 Ravine on west side, 2 miles south of Wyoming. Bristol shales.

68 Ravine on west side, 2½ miles north of Warsaw. Gardeau beds.

45 Fall brook ravine ½ mile southwest from Warsaw. Gardeau beds.

46 Gibson's glen, 2 miles south of Warsaw. Gardeau to base of Portage sandstone.

69 Oatka falls near Rock glen. Gardeau to base of Portage sandstone.

70 Quarries of Warsaw Bluestone Co. at Rock Glen. The Portage sandstones.

Tonawanda valley section

The western part of Wyoming county and southeastern part of Erie county is an elevated region in which the higher ridges and hills are 1500 feet to 1700 feet A. T. It is in the drainage area of Lake Erie and the Niagara river, and the streams flow toward the north and west, cutting a large number of valleys and deep ravines across the Portage rocks, in their rapid descent of 600 feet to 900 feet to the broad level area that borders the lake.

The valley of Tonawanda creek is the most easterly one. It extends southward from Attica for about 10 miles, is ½ to 1 mile wide, and its sides are steep slopes, in which several small streams have cut small gullies that expose the rocks.

The rock section begins along the Tannery brook in the northern part of the village of Attica, where there is a long exposure of the upper Genesee shales.

At the cascade 10 feet high, ½ mile above the old tannery, these light shales are succeeded by the black Middlesex shales.

The exposure continues a few rods up the stream, but the contact with the Cashaqua shales is covered. The Middlesex shales are also exposed in the bed of Tonawanda creek below the milldam in the village.

The Tannery brook is crossed by the Erie Railroad 1 mile west of the village, and about 50 rods south of the railroad there is a good exposure of the Cashaqua beds along the east branch of the stream.

Fossils are quite abundant here in the shales and in the numerous concretions.

The top of the Cashaqua shales and the lower part of the Rhinestreet shales are exposed a few rods farther south.

A thin layer of pyritiferous black slate near the contact line contains Bactrites, Orthoceratites and a few other fossils beautifully preserved in pyrite.

At Sierks station, 4 miles south of Attica, the upper part of the Rhinestreet shales is exposed in the bed and sides of Tonawanda creek and the alternating layers of light and dark shales of the base of the Hatch division on the hillside and along the railroad south of the depot. Some fossiliferous layers of light shale occur near the top of the exposed section and a row of large concretions a few feet above them.

At Varysburg, 8 miles south of Attica, there is an exposure of 25 feet of Gardeau flags and shales, with concretions and a few fossils, in the banks of Tonawanda creek, below the milldam in the village. With the exception of about 25 feet next above this exposure, that are covered, the Gardeau section may be seen in the bottom and sides of Stony brook, that comes in from the east through a deep ravine, and joins Tonawanda creek above the dam. This is a fine exposure, and it ends at the base of the Portage sandstones.

A small gully on the steep hillside west of Varysburg is crossed by the Buffalo, Attica and Arcade Railroad, at the altitude of 1240 feet A. T. Above the bridge about 250 feet of Gardeau flags and shales are exposed. A thin sandstone about level with the bridge contains fossil sponges. For 140 feet above this layer the beds are generally shaly, but flags and thin sand-

stones are frequent, and some of the shaly layers are quite sandy. A few of the sandstones are a foot or more thick and hard.

The Portage sandstones are exposed in the upper part of the ravine to the brow of the hill. Some of the layers are compact and heavy and have the same appearance as in the Genesee river section, but most of the bed is softer and laminated, and some parts are quite shaly. The thickness seems to be but about 75 feet, but the lower limit is not well defined.

The bed of soft olive and black shales that succeeds the Portage sandstones is exposed above the crest of the hill in a short shallow gully.

The Gardeau beds and the sandstones are also exposed in a similar ravine, 2 miles farther north, where the sandstones have been quarried for railroad purposes.

On the east branch of Tonawanda creek about 1½ miles above the forks and 5 miles south of Varysburg, a layer of calcareous sandstone outcrops in the bed of the stream for a few rods, and the same stratum appears in a small quarry ¼ mile northeast. It contains great numbers of small fragments of brachiopods, nearly all of which are too minute to allow identification of the species.

It bears a very close resemblance to the Long Beards riffs fossiliferous layer; it is the lowest horizon in which brachiopods were found in this section; as it is at the proper altitude, it is doubtless the same stratum, or, at least, in very nearly the same horizon.

On the south side of the Erie railway bridge at Griswold, 6 miles west of Attica, the Styliola limestone is exposed in the bed of Murder creek. It is 18 feet above the top of the Hamilton beds as exposed in the east bank of the stream 50 rods north of the depot, and is overlain by 13 feet of typical upper Genesee shales, above which are the black Middlesex shales.

A long flat exposure of the Cashaqua shales is in the bed and sides of the stream to the falls; including 5 feet of alternating light and dark layers at the bottom and 12 feet of the same character at the top, they are 77 feet thick here.

At the falls and in the ravine above, about 100 feet of black Rhinestreet shales are exposed.

A row of very large septaria, occurs in the black slates 28 feet above the top of the Cashaqua shales.

The Middlesex shales and the base of the Cashaqua shales are exposed in the bed of Ellicotts creek, 1½ miles west of the Erie Railroad station at Darien.

The bottom of the Cashaqua shales is level with the rails on the bridge. This is the most northern exposure of Portage strata in this State.

On Cayuga creek an outcrop at Iron Bridge Mills shows the Styliola limestone and 12 feet of Upper Genesee blue black shales above it.

At Cowlesville, 2½ miles south, there is a large exposure of the Cashaqua shales in the cliffs along the stream, and the Rhinestreet shales with many large septaria outcrop almost continuously below and above Folsomdale.

At and above the forks at Cayuga creek, 3 miles south of Folsomdale, the top of the Rhinestreet shales and about 100 feet of blue shales, in which thin layers of black slates and a few flags are intercalated, are exposed.

On Buffalo creek the upper part of the Cashaqua shales is exposed in the escarpment along the west side of the stream below the bridge at East Elma. Fifteen feet of black slates crop out 1½ miles up the stream, and at Porterville 100 feet of the Rhinestreet shales are exposed, in which two rows of very large septaria, separated by 35 feet of black slates, occur. Some of the septaria are 8 feet in diameter and 2 to 2½ feet thick.

At Johnson Falls, 7 miles up the valley southeast from Porterville, a small creek comes into the valley from the east over a high cascade and through a short but deep ravine.

There are 62 feet of Gardeau shales and flags exposed below the falls, and 144 feet in the face of the cascade and at the top.

The beds are principally soft bluish shales with flags and thin sandstones, that are more frequent and thicker toward the top.

The soft layers contain the common Portage fossils in small numbers, and crinoids and Aulopora also occur.

A layer of sandstone 2 feet thick, about 40 feet above the bottom of the cascades, contains fossil sponges.

The horizon is very nearly the same as that in which sponges occur at Varysburg. At the top of the falls a layer of compact blue sandstone 5 feet thick is overlain by 4 feet of shales, that are succeeded by another layer of sandstone like the one below and 10 feet thick. The strata next above are covered, but black shale is exposed slightly a short distance up the stream.

These sandstones are in the horizon of the Portage sandstones of the Genesee river section. They are near the surface over a large area in the town of Sheldon and outcrop in many places. They also outcrop frequently on the west side of the valley south of Johnsons Falls for 5 or 6 miles, to Java Village, where 8 feet of the upper bed are exposed on the upper side of the bridge over a small stream that comes in from the east through a deep ravine.

The sandstone is here succeeded by 15 feet of black shale, next above which there are 145 feet of soft blue and olive Wiscoy shales with thin bands of black slates and a few thin flags.

In the lower part of this section the rock is quite calcareous, and there are many concretions and concretionary layers. The upper part is more sandy. Buchiola speciosa and Palaeotrochus are common, and other Portage species occur in the lower soft shales.

A layer of calcareous sandstone, 1 foot, 8 inches thick, forms the crest of a cascade 15 feet high and is 160 feet above the sandstone at the mouth of the glen.

It contains many small fragments of brachiopods, very few of which are large enough for identification of species.

This stratum is in every way like the fossiliferous layer at the top of the Tonawanda creek section, the outcrop of which is 5 miles east of this point, and it is without doubt the same.

It is succeeded by 10 feet of softer, flaggy and shaly sandstone and 35 feet of hard blue shales in which there are a few even flags.

The only fossils found were a few brachiopods scattered through the shale and several impressions of Liorhynchus on the lower surface of a sandy layer.

On the east side of the valley of Cazenovia creek, 1½ miles north of Holland, the sandstones of the Portageville horizon are exposed in an old quarry and other places near the railroad, and the black shales that succeed them may be seen in the bed of the stream in the village.

In a small ravine on the east side of the valley a little north of the railroad station, there is an exposure that begins about 50 feet above the sandstones, in which there occurs, 100 feet above the bottom, a layer of calcareous sandstone a foot or more thick, of the same character as the one in this horizon in the Java Village ravine, except that no fossils were found in it. A loose slab, fallen apparently from but a few feet higher, contained Liorhynchus, Ambocoelia umbonata and Orbiculoidea.

Stations in the Tonawanda creek valley

25 Along the Tannery brook, 1 mile west of Attica. Exposed: upper Genesee, the Middlesex shales of the Portage and the Cashaqua shales.

26 Along Tonawanda creek and the railroad at Sierks station, 4 miles south of Attica. The top of the Rhinestreet shales and base of the Bristol shales.

27 Old quarry at the top of the hill on the west side, 1½ miles south of Sierks. The Gardeau beds and the base of the Portage sandstones.

28 Ravine on west side at Varysburg. Gardeau beds and the Portage sandstones.

29 The Stony brook ravine east of Varysburg. Gardeau beds.

30 Young's quarry, and along the east branch of Tonawanda creek, 4 miles south of Johnsonburg. Fossiliferous sandstone.

Stations between the Tonawanda valley and the shore of Lake Erie

31 Along Murder creek at Griswold station. Exposed: upper Hamilton, Genesee shales, the Styliola limestone, the Middlesex shales, the Cashaqua shales and the Rhinestreet shales.

32 Along Cayuga creek at Iron Bridge Mills. The Styliola limestone, Upper Genesee shales and the Middlesex shales of the Portage group.

33 Along Cayuga creek at Cowlesville. The Cashaqua shales.

34 Along Cayuga creek at Folsomdale. The Rhinestreet shales.

35 Along Big Buffalo creek at Porterville and East Elma. Rhinestreet shales and the Cashaqua shales.

36 Ravine at Johnsons Falls, 2 miles north of Strykersville. Gardeau to base of Portage sandstones.

37 Ravine at Java Village. Top of the Portage sandstones and the Wiscoy shales to Long Beards riffs sandstone.

38 Ravine east of, and along the railroad north of Holland. Portage sandstones and Wiscoy shales.

40 Ravine 1 mile south of West Falls. Gardeau beds.

Lake Erie section

The exposure of Portage strata on the shore of Lake Erie begins in the cliffs on the south side of the mouth of Eighteen Mile creek in the town of Evans, Erie co. and, through broken by many short stretches of sandy or gravelly beach, is almost continuous for 45 miles to the northwest corner of the town of Westfield, Chautauqua co. 8 miles from the Pennsylvania line.

But three of the subdivisions that can be made in the Portage formation in the Genesee river section can be identified here by the character of the sedimentation.

The Middlesex, the Cashaqua and the Rhinestreet shale are much alike in both sections except as to thickness, but above them there is in the lake section a thick mass of shales, light colored and more or less calcareous at places, black and bitu-

minous, in which flags or sandstones are absent from all the lower part, rare in the middle, and are a considerable portion of the sediment only at the very top of the section.

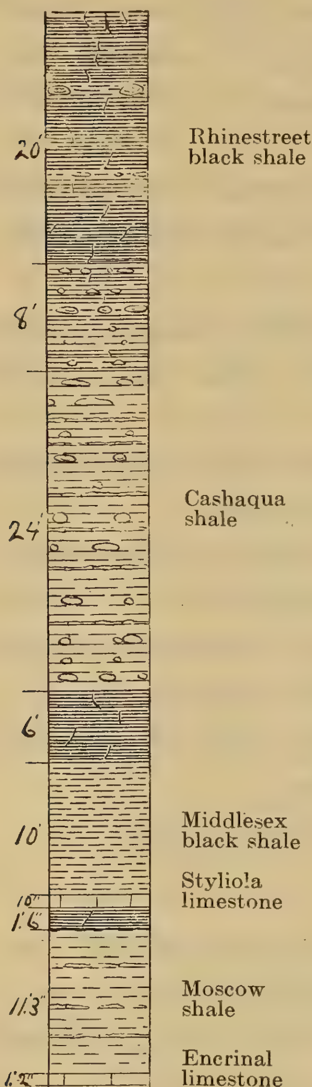


Fig. 8 Cliff section opposite Hotel Mortimer, Lake Erie shore near North Evans. Station 50

Calcareous concretions and concretionary layers are of frequent occurrence in all parts of the section.

Fossils are common in the lower and the upper beds but are very rare in the middle ones. The fauna is composed almost entirely of cephalopods, gastropods and lamellibranchs. C h o n e t e s l e p i d a occurs occasionally in the Cashaqua shales, a few Lingulas in the black slates and a small Productella near the top of the group were the only other brachiopods found.

In the exposure in the south shore cliffs, ¼ mile south of the mouth of Eighteen Mile creek, the Styliola limestone is separated by 1 foot of dark shales from the top of the Hamilton shale. This limestone is 6 inches thick and inclined to be shaly, but is more compact and 12 inches thick where it comes down to the lake level 1½ miles to the south. It is overlain by 11 feet of characteristic Upper Genesee shales, that are succeeded by the black Middlesex shale, which is here but 8 feet thick.

The Cashaqua shales, also exposed in the cliff, are 32 feet thick, and consist of 24 feet of very light colored clayey shales, and above these 8 feet of light and dark shales. Concretions are common throughout the formation.

The upper part of the cliff is in the horizon of the Rhinestreet shale, and the rock is all black slaty shale.

At the mouth of Pike creek 12 feet of Hamilton shales, the Genesee shales and the Middlesex are exposed.

The base of the Portage formation is 12 feet above the lake level.

Small Lingulas of two species occur in the black slates.

The lower part of the Cashaqua shales is not exposed along Pike creek, but above the highway bridge, 60 rods from the lake, the upper part is well exposed in the bottom and sides of the channel.

Fossils are common in the numerous concretions and some of the soft layers.

The contact with the Rhinestreet shale is at the bottom of a low cascade, and about 15 feet of the succeeding black slates are exposed in the sides of the ravine.

In the ravine of Eighteen Mile creek the Middlesex shale is exposed in the cliffs in the vicinity of the two railroad bridges, and it is at the water level on the east side of the upper one.

The lower part of the Cashaqua shales is covered in the bed of the stream, but the upper part appears in the escarpment on the east side 40 rods above the upper railroad bridge, and there is a large exposure of the same horizon in the creek bed above the highway bridge at North Evans and for 50 or 60 rods eastward to the old dam.

In the cliffs at the west end of the dam the contact with the Rhinestreet shale and 50 feet of the black shales may be seen.

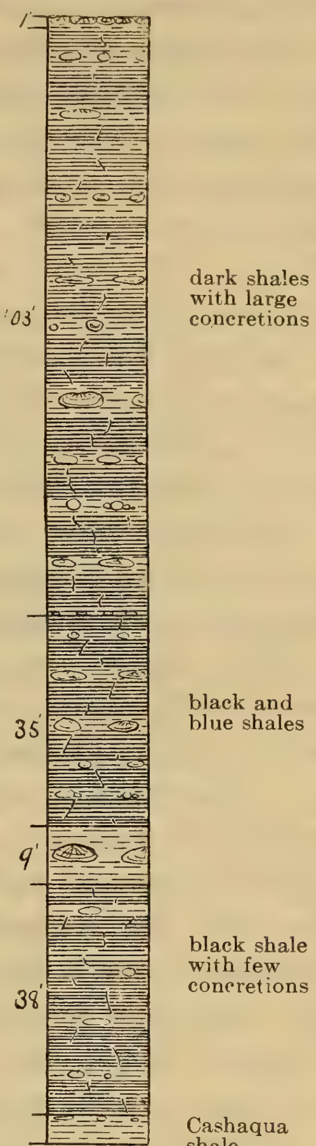


Fig. 9 Section on Eighteen Mile creek from North Evans to the railroad bridge at Eden Valley. Station 51

Impressions of goniatites are very common in the Cashaqua shales, and in the concretions also a small Loxonema. B u c h i o l a s p e c i o s a is very rare, but a few other lamellibranchs appear frequently. The shale in the softer layers has about the consistency of dried clay and the only hard layers

are calcareous and concretionary. Spherical concretions are numerous, and some of them are 1 foot to 3 feet in diameter.

The dugway roads leading down to the bridge at North Evans were excavated in the black Rhinestreet shale, and all of this formation is exposed in detail in the bottom and sides of the Eighteen Mile creek gorge between North Evans and the Erie Railroad bridge, 4 miles to the southeast. It is 185 feet thick in this section and is composed principally of bituminous black shale, but there are several layers of bluish shale, some of which are 6 feet to 8 feet thick, and in these lighter beds there are many large septaria and beautifully symmetric concretions.

In two or three rows in the upper part of the band the septaria reach a diameter of 6 feet to 10 feet and are 2 feet to 4 feet thick. The lighter layers contain a few fossils like those found in the Cashaqua beds.

The black slates are almost barren, except of plant remains, which are quite common. In the cliff at North Evans a small Lingula occurs in one of the lower black layers.

These shales are exposed at several places along the lake shore on the north side of Sturgeon point and along the railroads in the vicinity of Derby.

A concretionary layer 6 inches to 8 inches thick, the upper surface of which is a scraggly mass of angular fragments of impure limestone, separated by thin seams of spar, like the surface of a flat septarium but finer, is taken as the top of the Rhinestreet shale, the proportion of black shale above this horizon being less than the lighter. It is exposed under the Erie Railroad bridge over Eighteen Mile creek below Eden Valley and near Angola, and on the lake shore.

The lighter shales that succeed the Rhinestreet shale are exposed in a small ravine that comes into the gorge of Eighteen Mile creek from the east about 60 rods above the Erie Railroad bridge. The section covers about 100 feet, in which there are many large and small spherical concretions and others that are oblong and flattened. Very few of them are septaria.

This horizon is stratigraphically continuous with the Hatch shales and flags of eastern sections, but its lithologic characters have changed somewhat.

The same horizon is exposed in the cliff on the west side of the main ravine and in the creek bed below the highway bridge ¼ mile farther south.

The scraggy layer at the top of the Rhinestreet shale outcrops at the lake level at Fox's point on the south side of Dibble bay 2½ miles west of Angola, and about 60 feet of the light shales next above it and several rows of the large concretions are exposed in the escarpments along the shore for a mile to the mouth of Mud creek.

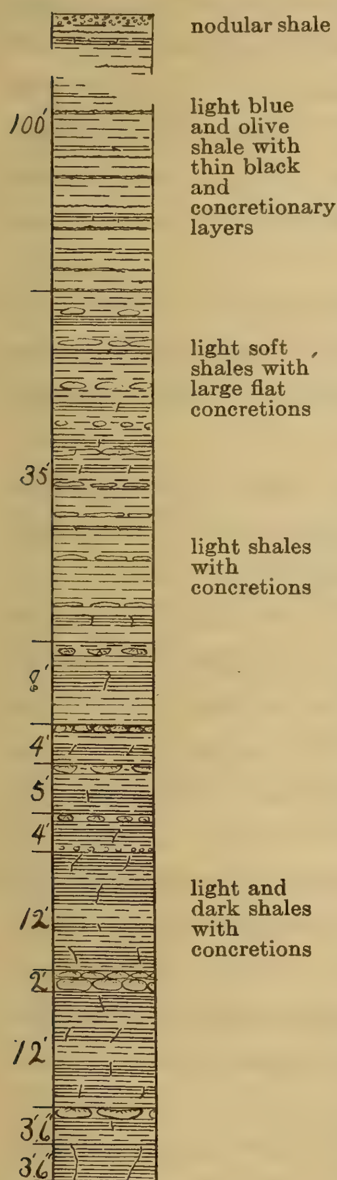


FIG. 10 Section on Big Sister creek from Evans Center to Pontiac. Station 52

The rock exposure on Big Sister creek begins about a mile from the lake shore. About 50 feet of the Rhinestreet shale may be seen in the bottom and sides of the creek in the vicinity of Evans and southeastward to the escarpment on the north side of the Angola cemetery. At the foot of the south end of this low cliff the concretionary layer crosses the channel, and it can be traced in the cliff, rising rapidly toward the north.

Between this layer and a soft calcareous sandstone 4 inches thick, containing many nodules of iron pyrites that is exposed in the cliff on the north side of the creek 20 rods above the Lake Shore Railroad bridge at Angola, there are 68 feet of light soft shales, in which there are a few thin, black layers and several rows of flattened concretions, from 2 feet to 4 feet long and 8 inches to 12 inches thick, besides many smaller ones.

M a n t i c o c e r a s r h y n c h o s t o m a and other cephalopods occur, finely preserved in the concretions and the shales contain a few lamellibranchs.

This horizon is the same as that at the top of the previously described section on Eighteen Mile creek. It is also exposed

along Delaware creek a mile west of Angola and in the escarpments on the lake shore, north of the mouth of Mud (or Farnham) creek.

Between the 4 inch sandstone in the escarpment at Angola previously referred to, and the top of the rock exposure at Pontiac there are exposed in the ravine of Big Sister creek about 100 feet of soft, light colored shales in which there are a few black layers, but no flags or sandstones.

Altogether the beds are much like the Cashaqua beds, except that concretions are much less frequent, and most of them are quite small, but there are many concretionary layers from 2 inches to 4 inches thick.

These beds are also abundantly exposed in the quarries of the Buffalo Sewer Pipe Co., ½ mile south of Angola, and along the Lake Shore Railroad in the rock cut between the Delaware creek culvert and Farnham.

A few low escarpments along the lake shore between the mouths of Mud creek and Cattaraugus creek are in the horizon of the upper part of the section on Big Sister creek.

At Pontiac there are two thin beds of light shale in which there are embedded great numbers of small calcareous nodules or concretions that give the beds a pebbly structure. They are separated by 4 feet of light shales, in which the pebbles do not appear. A layer of black slate 2 feet thick is 4 feet above the upper pebbly layer.

This horizon is exposed in the cliffs on the south side of Cattaraugus creek and a few feet above the water on the south side of the mouth of Silver creek.

The black layer appears in the bottom and sides of Walnut creek, near the Emke flouring mill in the south part of the village of Silver Creek.

There is an almost continuous exposure of upper Portage and lower Chemung strata along the channel of Walnut creek for more than 10 miles south from Silver Creek, the first 3 miles in a deep gorge.

In this ravine next above the 2 foot black layer near the mill, there are 112 feet of shales, nearly all light colored except two dark beds each 11 feet thick. The bottom of the first is 15

feet and the second 56 feet above the base of this section. These beds are equivalent to the upper part of Hatch flags and shales of eastern sections.

Dunkirk shale. A third black band, the Dunkirk shale, similar in character to the Middlesex and the Rhinestreet shales, succeeds the 112 feet of lighter beds and is 55 feet thick. At the bottom there are 35 feet of densely black, slaty shales, like those in the other black bands and containing the same species of Lingula.

The base of this shale is exposed in the cliffs on the south side of Dunkirk harbor and in the escarpments on the west side of Point Gratiot. The septaria are strewn along the beach 2 miles southwest in the vicinity of Van Buren point.

The same beds are exposed in the bottom and sides of Silver creek under the high bridge at Hanover Center and in two large ravines near North Collins, and along the highway on the hill 1 mile east of Eden Center in Erie county.

Above the Dunkirk shale light, soft shales again predominate, but layers of black shale from an inch to several feet in thickness occur very frequently, and concretions are common.

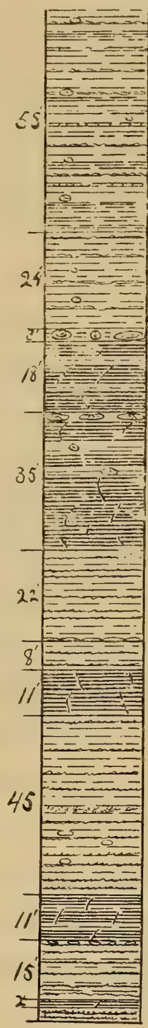


Fig. 11 Section on Walnut creek from Silver Creek village to Keech 's Corners. Station 55

A row of very large septaria 148 feet above the black band in the Walnut creek section appears on the lake shore opposite Brocton. A sandstone 4 inches thick lies just above the septaria and flags, and thin sandstones increase in numbers and thickness above this horizon. They are very rare below it. A band of soft shales 67 feet thick, in which there are a few flags but concretions are almost entirely absent, is succeeded by a band of similar shales and flags 25 feet thick in which there are several rows of concretions.

Fossils are common in a few of the layers of shale, and, in two rows of large flattened concretions, that are not septaria, there are some finely preserved cephalopods and large lamellibranchs. All these beds are stratigraphically equivalent to the Gardeau of eastern sections, more particularly its upper part, and probably in some degree to the Portage sandstone horizon.

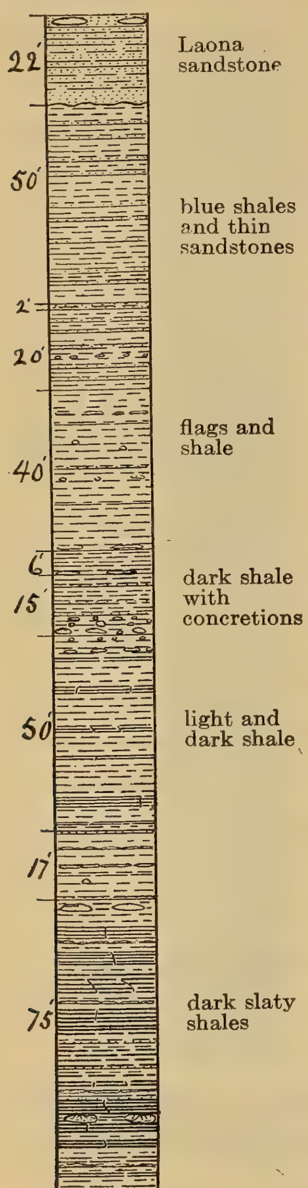


Fig. 12 Section on Walnut creek from Keech's Corners to sandstone at Corey's mill, Forestville. The upper part from the succession in Terry's ravine. Stations 60, 61

This horizon is exposed along Walnut creek below and above the Erie Railroad bridge at Forestville and in a small ravine ¼ mile west of Smith's Mills.

It is bare at the water level on the lake shore at Correll's point, opposite the village of Portland.

Next above the upper row of large concretions in the Walnut creek ravine at Forestville, there are 40 feet of soft, light and dark shales in which there are many small concretions and that are succeeded by a flaggy band 10 feet thick, that produces a cascade about 20 feet high by the mill on the north side of Main street.

Another band of light and dark shales with a few thin flags and small concretions, that is about 50 feet thick, overlies the flaggy band and is succeeded by a bed of sandstones and flags separated by thin layers of hard blue shales, that is 22 feet thick, the base of which is the top of the Portage formation on Lake Erie.

The Laona sandstone (Hall) is an arenaceous stratum well exposed at the falls in Terry's ravine, 1 mile northeast of Forestville, where brachiopods (S p i r i f e r d i s j u n c t u s etc.) occur abundantly in some of the light colored layers of sandstone, in place in the lower part of the stratum and in several large fallen slabs in the ravine below the falls.

It is also exposed in Faulkner's gulch, a ravine about 5 miles east of Terry's ravine on the road from Smith's Mills to Nashville, and a compact layer in the lower part contains brachiopods in still greater numbers, both of individuals and of species.

Some loose slabs in the gorge of Walnut creek, below the mill at Forestville, from this horizon also, contains brachiopods, but they were not found in place in the Walnut creek section.

The sandstones cause a cascade at Corey's mill, ¾ mile south of Forestville, and a layer about 50 feet higher, exposed in a small ravine a mile farther south, contains several species of brachiopods, and they also occur along the escarpment on the east side of the creek at Miller's Mills, a mile farther south.

A layer 4 inches thick, and quite calcareous, that is exposed in the bed of a small brook that flows through Forestville from the east, contains several species of brachiopods. The horizon is about 75 feet above the sandstones. There are several quarries and natural outcrops between Forestville and Laona in which the sandstones are exposed. At Laona they appear in the bed and sides of Canadaway creek, and one compact layer 5 feet thick has been quarried for more than 50 years.

In a soft layer in the bed of the stream about a mile south of Laona and 75 feet above the sandstones a few obscure impressions of indeterminable cephalopods were found.

No other representatives of the Portage fauna were found above the horizon of the Laona sandstone, in the Lake Erie section. On the lower surface of a thin sandstone, 10 feet higher, and in the subjacent shales, Chemung brachiopods are common.

Shumla sandstone (Hall). The sandstones exposed at Shumla 2½ miles south of Laona are 260 feet to 280 feet above the Laona sandstone. Fossils are very rare here, but a few specimens of a small Orthis and a small Productella are distributed through the beds and are quite common in the large concretions in a thick sandstone in the bed of the creek under the bridge.

The position of the Laona sandstone may be easily traced toward the southwest by the means of a number of small outcrops. It is exposed at Brocton in the bed of Slipperyrock creek near the bridge in the northwest part of the village and

in a field quarry 50 rods north; also in a small quarry 5 miles southwest from Brocton near the lake road, in the sides of a small ravine and in a quarry similarly situated 1 mile farther southwest.

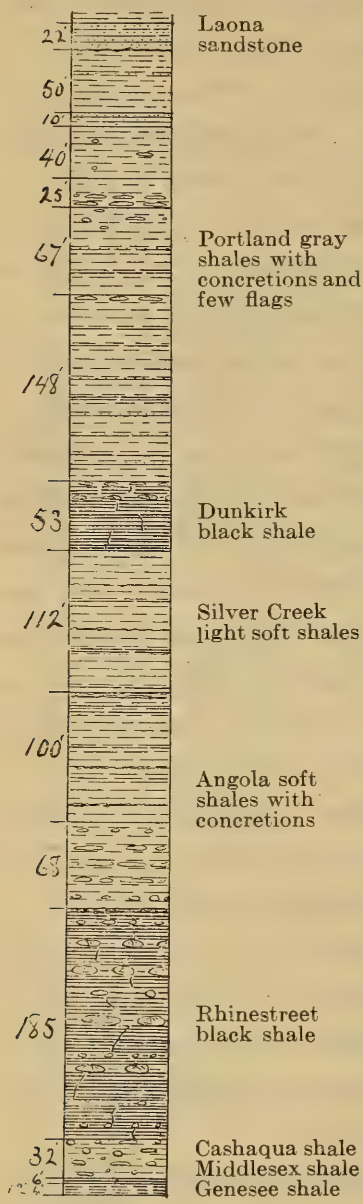


Fig. 13 Section on Lake Erie from top of Hamilton to top of Laona sandstone. Stations 50–64

The sandstones in this horizon are constantly thinner bedded and less compact in the exposures southwest from Forestville, and they appear in the upper part of the cliffs on the lake shore northeast from Barcelona (Portland Harbor) as a band of flags and thin sandstones and disappear under the waters of Lake Erie about a mile southwest from the mouth of Chautauqua creek and 9 miles northeast from the Pennsylvania line.

The sandstones of the Shumla horizon are exposed in the sides of Chautauqua creek ravine in the village of Westfield near the milldam, and in the cliffs along the lake shore from 1½ to 3 miles north of the state line, and they come down to the lake level under the gravelly beach ½ mile north of the state line.

Fossils of any description are exceedingly rare in the shales and flags between the horizons of the Laona and the Shumla sandstones along the lake shore, the only ones found being a few small brachiopods in the intermediate beds on Chautauqua creek and in about the same horizon in the bed of a small creek that flows into the lake near a fishing station 4 miles southwest from Westfield.

At Northeast Pa. Chemung brachiopods were found in small calcareous masses on the uneven upper side of a 4 inch flag and on the lower surface of a similar flag 5 feet higher, both of which are exposed in the bed of Twelve Mile creek, ¼ mile from the lake and about 30 feet above it.

In the 500 or 600 feet of shales and flags exposed along the bed of this stream above the horizon in which the brachiopods occur, and below the highly fossiliferous Chemung sandstones 3 miles east, plant remains are common, but other fossils have not been observed.

Stations on or near the shore of Lake Erie

50 The shore of Lake Erie from the mouth of Eighteen Mile creek to the mouth of Pike creek. Exposed: upper Hamilton shales, the Genesee shales, the Middlesex shales of the Portage group and the Cashaqua shales.

51 The ravine of Eighteen Mile creek, from North Evans to Eden Valley. The Cashaqua shales and the Rhinestreet shales.

52 Along Big Sister creek from Evans to Angola and Pontiac. The Rhinestreet shales and the Bristol shales (or Angola shales).

53 Along the lake shore from Fox's point to the mouth of Mud creek. Bristol shales.

54 Along the lake shore from Irving to Dunkirk. Silver Creek shales.

55 Walnut creek ravine from Silver Creek to Keech's Corners. Silver Creek shales and Point Gratiot shales.

56 The lake shore from the mouth of the Little Canadaway creek to the mouth of Slipperyrock creek, opposite Brocton. Portland shales.

57 Lake Shore at Correll's point. Portland shales.

59 Along Silver creek at the High bridge and Smith's Mills, and ravine 1 mile west of Smith's Mills. Portland shales.

60 Along Walnut creek at Forestville. Portland shales.

61 Terry's ravine, 1 mile north of Forestville. Portland shales and the Laona sandstones.

62 Lake shore in western part of the town of Westfield. The Laona sandstones.

64 Along Canadaway creek at Laona. The Laona sandstones.

Along Twelve Mile creek ¼ mile from the lake shore at Northeast Pa. Thin sandstones containing brachiopods.

STRATIGRAPHY OF BECRAFT MOUNTAIN[1], COLUMBIA COUNTY, N. Y.

With stratigraphic map and sections

BY AMADEUS W. GRABAU

Introductory

Becraft mountain, close to the city of Hudson, has been known to geologists since the early days of geologic study in the State of New York, and descriptions of it play an important part in the early reports on the geology of the State. In a letter dated Dec. 3, 1820, and published in *Silliman's Journal* for 1822[2], Mr John P. Jenkins, of Hudson N. Y., gave a brief description of Becraft mountain. He calls it " . . . a solid mass of gray rock supporting a blue compact limestone; the upper strata of both rocks contain a great variety of petrifactions which have been described by Mr Eaton and others."

In 1823 Silliman described the "marble of Hudson," which was wrought by Mr Charles Darling of that city. He considers it of high class, and similar to that of the Peak of Derbyshire. The "marble" is the Becraft limestone of Becraft mountain.

Mather[3] in 1838 gives a description of the strata of Mount Becraft and of Mt Bob, which lies a little to the north, as well as their general structure, and states that the limestone of the mountains lies unconformably on the Hudson river slates. In 1840[4] he compared the strata of the Helderberg mountains with those of Becraft, considering them similar. In 1841[5] he again refers to Becraft, emphasizing the unconformity between the "nearly horizontal" Helderberg limestones, and the "highly inclined" subjacent Hudson river strata.

In his final report, 1843[6], Mather describes Becraft mountain, and gives three sections to illustrate the structure. The descrip-

[1] Topographically Becraft mountain would be considered a hill, since the highest elevation on it is less than 500 feet above the sea. Structurally, however, it is a section of a mountain range. All the localities may readily be visited in a short walk from Hudson N. Y., where good accommodations may be obtained at the Worth house, or in private boarding houses.

[2] Am. Jour. Sci. 1822. 4:33.

[3] Geol. N. Y. 1st Dist. 2d An. Rep't. 1838. p.165, 166.

[4] Geol. N. Y. 1st Dist. 4th An. Rep't. 1840. p.238.

[5] Geol. N. Y. 1st Dist. 5th An. Rep't. 1841 p.90.

[6] Geol. N. Y. 1st Dist. Final Rep't. 1843. p.344–52, pl. 24, fig. 4–6.

tion is largely a repetition of that of 1838. He recognizes three formations overlying the Hudson river beds, viz (1) the Waterlime group, including the Tentaculite limestone (Manlius), (2) the Catskill shaly limestone (New Scotland), and (3) the upper, Scutella, or Sparry limestone (Becraft). The Coeymans and Kingston were not differentiated from the limestones respectively underlying each, and the higher strata were not recognized. He determined the essential basin-shaped structure of the mountain, and the unconformity between the lowest bed of the series, and the underlying tilted and eroded Hudson river strata. This unconformity is depicted in his section 6, which furthermore illustrates with section 4, what he believed to be a series of tilted fault blocks. This structure was undoubtedly suggested by the numerous cuestalets which characterize the outcrops of the New Scotland, and to some extent the other beds also. The steep infaces or fronts of these erosion ridges and the surface slopes of their tops, which follow the dip, have all the aspect of the corresponding faces of slightly tilted fault blocks [fig. 1, a, b]. Mather also gives a section of the southeast end of Becraft mountain, which shows the overturned strata on the east.

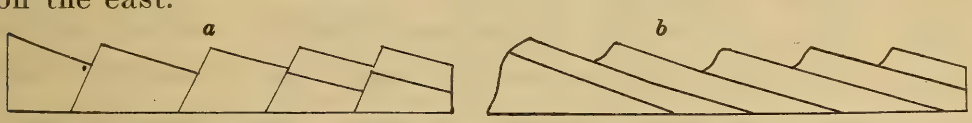


Fig. 1 Diagram illustrating the detailed structure of parts of Becraft mountain: *a*, as interpreted by Mather; *b*, as actually existing.

In 1846 Emmons[1] gave a section of the southeastern end of Becraft mountain, showing a conformable relation between the Hudson river and overlying waterlime. He also speaks of a mass of Calciferous sandstone supported by the Taconic slate. This refers probably to the hill of Burden conglomerate opposite the center of the eastern face of the mountain.

In 1858 Rogers[2] mentions the unconformity at Becraft, which he states he discovered in 1837. He says:

The lower Helderberg or Pre-meridian rocks are seen in horizontal stratification in the hill, while the Hudson river slates

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[1] Agriculture of New York. 1846. 1:136.
[2] Geology of Pennsylvania. 1858. 2:785.

around its base are steeply inclined, and contorted from a movement previous to the deposition of the shales and limestones upon them.

Hall in 1859[1] expressed a doubt as to the reported unconformity between the Hudson river and Lower Helderberg strata, since "in Becraft's mountain the strata of this age [Lower Helderberg and Waterlime] lie inclined above the Hudson river group, and there appears no positive evidence of their unconformability."

The most complete review of the literature of Mt Becraft and the neighboring region on both sides of the Hudson is given by Davis in his article on the folded Helderberg limestones east of the Catskills.[2] From a study of this region on the west bank of the Hudson, he concludes that the contact between the Hudson river shale and the Waterlime is a conformable one, though he considers this conformity difficult to understand in view of the variation of the strata.

In 1883[3] Davis published the first geologic map of Becraft mountain and gave the first comprehensive account of its stratigraphy and structure. The map is accompanied by a number of cross sections, which give the main structural features of the range. He recognizes the Waterlime (Manlius) resting on the Hudson river beds and discusses at length the evidence for and against the unconformity between the two. While leaning toward the acceptance of an unconformity, he nevertheless considers the evidence for it still insufficient. Above the Waterlime he recognizes the Lower Pentamerus (Coeymans), the Delthyris shaly (New Scotland), the Upper Pentamerus (Becraft), the Cauda-galli (Esopus) and the Corniferous (Onondaga). He did not differentiate the Kingston (Port Ewen) and Oriskany from the Becraft, nor the Schoharie from the Esopus. He also recognizes the complicated southeastern portion of the mountain.

Clarke[4] has published the latest and most complete map of Becraft mountain extant. In this all the formations are de-

[1] Palaeontology of New York. 1859. 3:39.

[2] Mus. Comp. Zool. Bul. v.7 (Geol. Ser. v.1) p.311-30, pl.12-13

[3] Am. Jour. Sci. ser. 3. 1883. 26:381-89.

[4] Clarke, J. M. Oriskany Fauna of Becraft Mountain, Columbia County, N. Y. N. Y. State Mus. Mem. 3. 1900.

picted in their proper relation, he having added to those recognized by Davis, the Schoharie, the Port Ewen and the Oriskany, the latter formation having been discovered by Beecher and Smock at Becraft in 1890.[1]

No attempt was made by Clarke to depict the minute details of the distribution of the formations, nor to map the complicated structure. The latter could be worked out only by a minute following of the outcrops over the entire field, and by a careful determination of the beds in isolated outcrops. For the latter work, paleontologic data had to be relied on fully as much as lithic characters, since the latter are often nearly identical in distinct horizons.

The desirability of a carefully constructed map of Becraft mountain has long been felt, not only on account of the interesting stratigraphic as well as tectonic features, which throw light on the problem of Appalachian stratigraphy and structure, but also on account of the fact that Becraft mountain forms an ideal region for field work with students in geology. Being isolated from the rest of the Helderbergs and of conveniently small size, it presents a problem of proper circumscription to enable something like completion to be attained by the students in the field. Its range of strata, with their well preserved fossils, most of which are limited to few or only one of the horizons; the various complications by folds and faults of several ages, together with all the more prominent tectonic features accompanying them, and the interesting stream adjustments and other physiographic features, make this an almost unrivaled field for classwork. Recognizing this fact, Dr John C. Smock, of Hudson, had constructed a detailed topographic map of the region, on the scale of 6 inches to the mile, and with contour intervals of 10 feet. This map has served as the basis of the accompanying geologic map, which was prepared under the auspices of Prof. John M. Clarke, the state paleontologist, and with the partial cooperation of stu-

[1] Beecher, C. E. Notice of a New Lower Oriskany Fauna in Columbia County, New York, with an annotated list of fossils by J. M. Clarke. Am. Jour. Sci. 1897. 44:410-14

dents in the Summer School of Geology in Columbia University. Nearly all the collections of fossils which have served as the basis of the accompanying faunal lists, were made by the university parties under the direction of the instructors. The collection, however, on which the list of Port Ewen fossils is based was made by myself, that I might be certain of the range of the species. A general map was prepared by the field parties, which afterward served me as a further basis for detailed study.

I wish here to express my indebtedness to Prof. John C. Smock, who not only furnished us with the accurate topographic base map, but also rendered other assistance during the progress of the field work.

STRATA OF THE BECRAFT REGION

The following formations are exposed at Becraft mountain. The thicknesses appended are the best estimates, whenever actual measurement was not possible.

			Feet
Devonic	11	Onondaga limestone	20–25
	10	Schoharie grit	200
	9	Esopus grit	100
	8	Oriskany quartzite	1–2
	7	Port Ewen (Kingston) limestone	25
	6	Becraft limestone	40–45
	5	New Scotland shaly limestone	70–75
	4	Coeymans limestone	42–45
Siluric	3	Manlius limestone	55
Champlainic	2	Hudson river slates	.....
	1	Burden conglomerate	.....

1 BURDEN CONGLOMERATE

This name is proposed for a calcareous conglomerate in which the pebbles are chiefly limestone embedded in a silicious sand, which in turn is held together by a more or less calcareous cement. The limestone of the pebbles is in part a gray, compact rock (calcilutite[1]) not unlike the Manlius limestone and in part a more granular mass (calcarenite (Grabau)). The matrix is

[1] Grabau. Science Feb. 20, 1903. p. 297. Also Geol. Soc. Am. Bul. v. 14; Paleozoic Coral Reefs, with notes on the classification of limestones.

generally stained with iron hydrate, and at the Burden iron mine this rock is in intimate association with the iron ore.

Davis described this rock,[1] assigning to it an age "apparently younger than the Helderberg series, and certainly much older than the drift." He thought that the limestone fragments "seem to correspond with the several subdivisions of the Lower Helderberg." He found it at two localities, one in the meadow south of Academy hill and one in the fields a quarter of a mile south of the southern end of the mountain. It is well exposed on a little stream which enters Claverack creek at a point about east of that where fault 16 strikes the eastern bounding road of the mountain. The stream lies on a fault line. It has cut back some distance from Claverack creek and forms a fall over the hard conglomerate, which fall has been utilized as a site for a dam and mill. The conglomerate bed is about 10 feet thick at the fault. It dips northeastward and abuts against what are probably the Normans kill shales, which have a similar dip. The conglomerate increases in thickness away from the fault and forms a prominent hill between the road and the stream. It is underlain by shales similar to those on the opposite side of the fault [fig. 2].

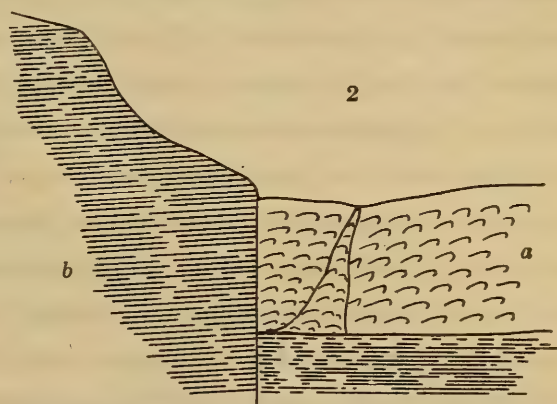

Fig. 2 Fault between Burden conglomerate (*a*) and Normanskill shales (*b*)

The age of this conglomerate is unknown. That it belongs to the Hudson river series is undoubted, but whether older or younger than the Normans kill shales, has not been ascertained. No fossils have been noted in the pebbles of limestone, though some search has been made for them. The position and character of the bed indicate that the rock is older than the beds composing Becraft mountain, for all these beds with the exception of the Manlius are highly fossiliferous and easily

[1] Am. Jour. Sci. 1883. 26:382.

recognizable. It may correspond to the Trenton conglomerate of Rysedorph hill described by Ruedemann,[1] or it may be of still earlier date. Its areal relations seem to indicate that it is older than the Normans kill beds of Mt Moreno. Boulders of this rock have been found on Becraft mountain in such a location that they could not well have been derived from any known outcrop. They therefore suggest other outcrops to the north or northeast of Becraft mountain.

2 "HUDSON RIVER" SHALES

Ruedemann has shown that the Hudson river shales do not constitute a single stratigraphic unit but rather comprise all the formations from the Beekmantown up to the top of the Lorraine. Nevertheless, these shales constitute a formational unit, with but slight lithic variations, representing continuous deposition, and hence it is advisable to retain the local name, Hudson river group or shales, for this series. At Mt Moreno these shales contain a typical Normans kill fauna in the higher beds. Clarke cites Coenograptus gracilis, Didymograptus sagittarius, D. tenuis Hall and other species of graptolites.[2] In the lower beds Phyllograptus was found by the Columbia field party. A recent visit in company with Dr Ruedemann resulted in the rediscovery of the Phyllograptus beds in the lower layers at the northwest end of Mt Moreno. In these Dr Reudemann identified Phyllograptus angustifolius Hall, Trigonograptus ensiformis Hall, Climacograptus pungens Rued. (ms), Diplograptus dentatus Brogn. and Phyllograptus postremus Rued. (ms). Dr Ruedemann refers these beds to his third Deep kill zone or zone with Diplograptus dentatus which may represent a Beekmantown horizon. Though no fossils have been obtained from the Hudson river shales of Becraft mountain, it is probable that they are of the same, or perhaps somewhat earlier age. Some of the strata underlying the mountain are somewhat more compact and firmer textured

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[1] Ruedemann. Trenton Conglomerate of Rysedorph Hill. N. Y. State Mus. Bul. 49. 1901. p.3.

Oriskany Fauna of Becraft Mountain. 1900. p. 7, footnote.

than those of Mt Moreno, as noted by Davis. Beds of hard siliceous limestone are also found intercalated among the other strata. Similar beds are met with on Mt Moreno.

Contact between the "Hudson river series" and the Manlius formation. This contact is everywhere a markedly unconformable one, the Hudson river strata being much folded and truncated by erosion before the deposition of the Manlius limestone. The unconformity takes the place of the strata from the Medina to the Waterlime of Buffalo inclusive, which apparently were never deposited in this spot. The later Champlainic strata, including the Lorraine, Utica and probably part of the Upper Trenton, and perhaps also the Oneida conglomerate, were worn away during the period of deposition of the Siluric strata west of the Hudson.

The actual contact between the Champlainic and Siluric strata is shown only in a few places at Becraft. The most important of these is at the outlet of the spring supplying the Hudson aqueduct. This is at the extreme northern point of the mountain. The dip of the Hudson river strata here has not been ascertained, but the cleavage planes stand vertical. The Manlius rests directly on the Hudson river strata. Another exposure of the contact is on the old tramroad leading to the quarries, a little north of the Jonesburg road. The strike of the Hudson river beds is here n. 50° e. and the dip is 35° s.e., the rocks being thin bedded and fissile. The Manlius is seen in the upper part of the cliff, but much disturbed by frost action and slipping, so that the precise character of the contact can not be determined. The dip of the Manlius a little higher up the cliff is from 10° to 12° eastward. A few exposures of the Hudson river beds in the Ancram road south of this, allow the approximate continuation of the contact line.

The most continuous exposures of the Hudson river—Manlius contact are found on either side of Fred. G. Lambert's farm, in the hills facing faults 20 and 21 [*see* map]. Here 80 feet or more of the Hudson river shales are exposed and the contact can be traced on both sides for several hundred feet, though generally the actual line of contact is covered. The Hudson

river beds are much disturbed. Between faults 18 and 17 exposures of both rocks allow the tracing of the contact line with fair accuracy, but beyond that the contact can be only approximately determined, since the exposures of the Hudson river beds are found only at intervals and then at some distance from the Manlius exposures.

That there actually is an unconformity between the two sets of strata hardly admits longer of a doubt. Besides the clear indication of the disturbance of the Hudson river strata and the erosion of their upper surfaces, the great time hiatus, extending from the middle Lower Siluric to near the top of the Upper Siluric, is sufficient indication of an unconformity and would

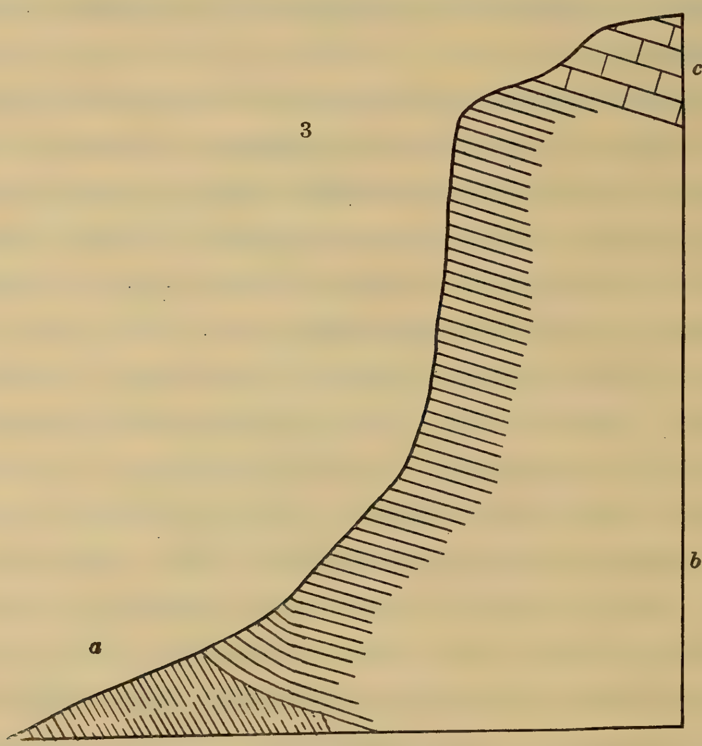

Fig. 3 Contact of Manlius limestone (*b*), with Hudson river shales (*a*) and Coeymans limestone (*c*), northern margin of Becraft mountain

be, even if this were not brought out in the structure. Such an absence of formations, when not due to faulting, as is clearly not the case here, can be accounted for only by nondeposition or by subsequent erosion. And the former in this region at least is, like the latter, indicative of land conditions.

3 MANLIUS LIMESTONE

The best place for the examination of the Manlius limestone of Becraft mountain is along the northern margin of the mountain, in the city quarry, and at the Hudson aqueduct. At the latter place, just west of the old tavern in Greenport, the entire thickness is shown. At this point a powerful spring issues from the mountains, the water of which supplies the pumps in the city of Hudson. In the bed of the stream formed by this spring the "Hudson river" slates are exposed. They are much contorted and cleaved, the cleavage planes standing vertical. The direction of bedding could not be determined. Resting on this are the lower Manlius beds, with a dip of 35° to 40° southward, the strike being n. 70° e. A little higher up the dip flattens to 20°, which is normal for the rock at this point. The measurements at this point are as follows [*see* fig. 3]:

	Feet
From basal contact to base of vertical cliff, the interval being a slope with the rock more or less concealed.....	18
Hight of cliff portion 34 feet, which, with dip of 20° gives for the thickness of the beds.........................	32
Thickness of beds forming upper slope from edge of cliff to contact with overlying Coeymans.................	5
Total thickness of Manlius......................	55

No fossils were found at this place.

At the city quarry in the cemetery off the Newman road (middle longitudinal mountain road) a total of 28 feet of the Upper Manlius is exposed, only 18 feet of which however are shown in the northeastern end of the quarry wall. It is overlain by 32 feet of Coeymans limestone. (Fig. 4)

The limestone in this as in the other exposures is a compact finely stratified lime-mud rock, a type of deposit for which the name calcilutite has recently been proposed.[1] L e p e r d i t i a a l t a is fairly abundant in certain layers in the upper part of the series, and is the only fossil found in these beds outside of the Stromatopora layers noted below. The dip of the strata is 12° s.e., the strike is n. 40° e.

[1] Science. n. ser. Feb. 20, 1903. p. 297.

Just below the lowest bed of the Coeymans limestone occurs the upper Stromatopora bed, forming the topmost layer of the Manlius. It averages 3½ feet in thickness, varying between 3 and 4 feet, and is for the most part made up of masses of stromatoporoids piled one above the other. In weathered sections these masses are well shown, being less readily seen in the fresh section on account of the massiveness of the rock. Sometimes at the edge of the cliff they are weathered out, so that they look like piles of boulders. The largest head measured is about 1½ feet in diameter. The bed immediately above this layer contains Favosites, crinoid joints and Gypidula galeata, and in texture is finely crystalline. This crystalline matrix frequently extends down between the Stromatopora heads, but more frequently the fine mud-rock fills the interstices between the masses of hydrocoralline. The lower line of the Stromatopora bed is very irregular, and sometimes a Stromatopora is embedded in the stratified Manlius below.

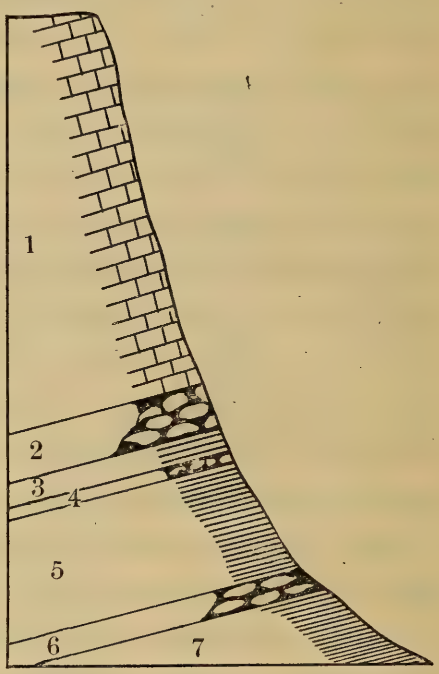

Fig. 4 City quarry, Hudson ; 1, Coeymans; 2, 4, 6, upper, middle and lower Stromatopora beds; 3, 5, 7, Manlius.

The "Stromatopora" fragments probably all belong to the genus Syringostroma of Nicholson, but their exact determination is a matter of great difficulty on account of their unsatisfactory preservation and it has not been attempted.

Besides the stromatoporoids, the following fossils characterize this bed.

Spirifer vanuxemi Hall

This species is represented by a few individuals in the upper Stromatopora bed. They agree substantially with the figure of Orthis plicata given by Vanuxem, which is the characteristic Manlius limestone species of eastern New York. The median sinus of the pedicle valve of our specimens is shallow,

rounded at the bottom, and somewhat narrower than is usual in this species. It is flanked by about four rounded plications on each side, which widen gradually toward the front of the shell. The brachial valve has four plications on each side of the central fold, the fourth being very short and much fainter than the others. The median depression along the top of the fold is marked in some cases, in others it does not occur at all. The plications, as well as the sinus and fold, extend to the apex. So far as I have been able to examine specimens of S. vanuxemi typical of the Manlius of eastern New York, the depression in the median fold of the brachial valve, where it occurs, is a feature of maturity rather than characteristic of the entire shell. In a few cases the depression in the fold can be traced nearly or perhaps quite to the apex of the valve. When the depression is well marked, the plications appear sharper and comparatively narrower. They also extend farther up the beak. On the other hand, it appears to be the case that, when the depression in the fold is faint or absent, the plications are less defined and near the apex become obsolete. Nevertheless, there are individuals in which the depression in the fold and the broadly rounded plication occur together. Finally, individuals occur (as figured by Hall) in which the apical portion is free from plications, these beginning part way down. In this case they are, so far as observed, broad and rounded.

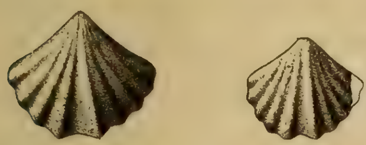

Fig. 5 Spirifer vanuxemi, pedicle valves

The young individuals of the species are in all cases marked by less pronounced and fewer plications. In certain forms, which may be considered the more primitive representatives of the species, the young are practically free from plications, or if these occur, they are broadly rounded and low, one or two only occurring on each side of the fold or sinus. From these considerations we arrive at the conclusion that the ancestral type from which S. vanuxemi was derived, was a pauciplicate if not nonplicate form. Furthermore, that those individuals among the species which have few and low plications, with a

smooth apical portion, are the least accelerated, while the extreme of acceleration would show strong plications on the beak, with a median depression on the fold, which in extreme cases commences near the apex. In rare cases is there a faint median fold in the sinus of the pedicle valve. Similar modification through greater or less acceleration is found in the mid-Siluric relative of this species, S. crispus, which seems to be a parallel development.

Spirifer corallinensis Grabau

Geol. Soc. Am. Bul. 1899. 11:352.

This name was proposed, as a varietal one, for the characteristic Spirifer of the Coralline (Cobleskill) limestone of Schoharie. This was referred by Hall to S. crispus and figured on plate 74, *Paleontology of New York,* v.2. The type specimen[1] is transverse, wider than high, with rounded ends. The sinus of the pedicle valve is very shallow, rounded and narrow. Beak of pedicle valve incurved and area comparatively low. In this respect the species is like S. crispus. In a weathered-out specimen surface markings similar to S. crispus are shown.

Fig. 6 Spirifer corallinensis, pedicle valve

This species approaches closest to the simpler types of the New York S. crispus, that with fewest plications. A specimen from Lockport [Am. Mus. col. $\frac{1771}{1}$] shows the relatively high and subrhomboidal outline, with a shallower sinus, which is rounded and widens less rapidly than in the normal form of S. crispus. There is one moderately strong and one very faint rounded plication on each side of the sinus, and two similar though fainter plications on each side of the fold.

Dimensions of the type specimen, length 11.5 mm, hight of pedicle valve 10 mm, of brachial valve 8 mm, transverse diameter 7 mm. Another characteristic specimen from the same bed (Coralline of Schoharie) is figured by Hall [fig. 8d]. It is proportionally narrower than specimen fig. 9d–f, and has a somewhat more pronounced almost subangular sinus. The width of this specimen is 11 mm, hight of pedicle valve 10.5 mm.

[1] *Op. cit.* pl. 74, fig. 9 d-f. Am. Mus. col. no. $\frac{1771}{4}$.

Still another characteristic pedicle valve from the same horizon has a width of 13 mm with a hight of 16 mm, but is very ventricose, appearing proportionally higher. The plications are almost invisible and the sinus narrow, very shallow and rounded.

This species is well represented in the upper Stromatopora bed of the Manlius limestone in the city quarry at Becraft. Its main distinguishing features are its subrhomboidal outline, shallow, narrow and rounded sinus, and obsolete or faint, broadly rounded plications. In the latter two features it differs materially from S. eriensis Grabau.

Measurements of two characteristic pedicle valves from this bed give

	1	2
width in mm.	12	12
hight in mm.	9	10

A comparison of typical S. coralliensis with the types of S. modestus from Cumberland Md. shows a close relationship, the latter differing chiefly in its extremely shallow sinus and faint fold, and in the total absence of plications. Specimens similar in most respects to typical S. corallinensis have been found in the Cumberland strata.

Spirifer eriensis Grabau *var.*

Geol. Soc. Am. Bul. 1899. 11:366, pl. 21, fig. 2a-b

A variety of this species is more common in the upper Stromatopora bed at Becraft than S. corallinensis. It is char-

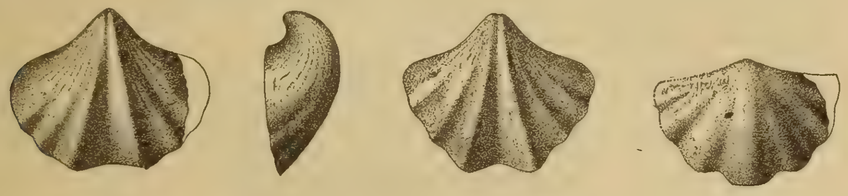

Fig. 7 Spirifer eriensis var.

acterized by a deep angular sinus with straight sides which diverge uniformly and regularly forward. It has narrow and more widely separated plications than S. corallinensis, and they become faint or obsolete in the upper part. A moderately strong plication occurs on each side of the sinus and

another weaker one outside of this on each side. There are faint indications of a third one beyond that. The shell is characterized by fine regular concentric lines which mark the edges of narrow imbricating lamellae. Fine radiating lines, interrupted by the concentric lines, are visible on well preserved specimens, giving a surface sculpture essentially like that of S. corallinensis, S. vanuxemi and S. crispus. The fold of the brachial valve occasionally shows a faint longitudinal depression.

Measurement of specimens from Becraft mountain.

	Width in mm	Length in mm
Pedicle valve	14	11
" "	13	11
" "	14.5	11
Pedicle valve of type specimen	10	8.5

Compared with the type from Williamsville, the present specimens, though generally larger, are very similar. The outline and median angular depression are alike in both. Only the lateral plications of the pedicle valve are more rounded and less widely separated in the Williamsville specimens than in the Becraft specimens. The number is also less, so that, whereas in the Williamsville specimens there is a total of eight plications, only six can readily be made out in the Becraft specimens. The concentric surface striae are the same in both. The brachial valve of the Becraft specimens is somewhat more convex, with the plications a little more pronounced, particularly the ones next to the median fold.

A single specimen from the Cobleskill of Schoharie (Am. Mus. 1856, with Atrypa lamellata) approaches closely to S. eriensis. The sinus widens regularly forward and the sides are flat; the bottom, however, is still rounded.

Genetic relationship of the Spirifers of the S. crispus type

The similarity between S. corallinensis of the New York Manlius and Cobleskill and S. modestus of the Manlius[1] of Cumberland Md. has already been referred to. It

seems probable that S. corallinensis was derived from a smooth form similar to S. modestus,[1] though the chances of its having been derived directly from that form are slight. A type which answers more readily the requirements of a radicle for this species as well as the others of this group, is Spirifer petilus Hall of the Niagaran beds of Waldron Ind. This species in the adult stage has all the characters of the young of S. crispus var. simplex and S. crispus, as pointed out by Beecher and Clarke.[2] S. corallinensis and S. eriensis are connected by intermediate forms. In some specimens from Becraft mountain, which show the adult characters of S. eriensis, the younger portion of the shell has all the characters of S. corallinensis with narrow shallow sinus and obsolete plications. As the shell is exfoliated, it is not possible to say whether or not the plications are wholly absent in the young, as appears to be the case.

The derivation of S. eriensis from S. corallinensis is then very clear, this being shown by morphogenesis as well as chronogenesis. In like manner it can be shown that S. vanuxemi was derived from S. corallinensis by an accelerated development of the plications, while the fold and sinus were retarded. The most accelerated individuals of S. vanuxemi have, as already pointed out, a depression along the middle line of the fold which in extreme cases reaches the beak. These three species, S. corallinensis, S. eriensis and S. vanuxemi, though occurring in the late Siluric beds, are all retarded in development with reference to the plications, when compared with S. crispus, which was derived from the same stock in the Midsiluric. In fact, these late Siluric species, if not known to occur above S. crispus, would be placed chronologically below or with that species Regarded however as retarded types, placed in an unfavorable environment, their more primitive characters are understood.

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[1] Schuchert has recently pointed out [U. S. Nat. Mus. Proc. 1903. 26:413] that a number of the species referred to the Cumberland Helderbergian really belong to the Manlius horizon of that locality. Among these is S. modestus.

[2] N. Y. State Mus. Mem. 1. 1889. p.75.

S. petilus of the Waldron Siluric beds is succeeded genetically, though not chronologically, by S. crispus simplex, and this in turn by the normal S. crispus. There is also a strongly accelerated type in the Waldron beds which is characterized by a depression in the fold and rarely an elevation in the sinus, and by angular plications.

The normal New York type of S. crispus has strongly rounded but narrow plications, with a moderately deep, rounded sinus, which broadens strongly toward the front. This species was undoubtedly derived from the Waldron S. crispus by migration. Whether the pauciplicate rhombic type above mentioned is due to a direct immigration or to retardation of the normal S. crispus of New York can not be readily determined. The same may be said of S. bisulcatus Vanuxem, which is still more primitive, or more retarded. The results of our present studies in the phylogeny of these species may be summed up in the annexed diagram.

Western New York	Waldron Ind.	Eastern New York	Cumberland Md. etc.	
		S. vanuxemi biplicatus		*Cayugan*
		S. vanuxemi	*S. vanuxemi*	
S. eriensis		*S. eriensis*		
		S. corallinensis	*S. corallinensis*	
			S. modestus	
	S. crispus biplicatus			
S. crispus <	*Spirifer crispus*	? *S. modestus* ?		*Niagaran*
S. crispus pauciplicatus				
	Spirifer crispus simplex			
.*Sbicostatus*	? <			
	Spirifer petilus >			

Camarotoechia hudsonica sp. nov.

Shell in form and size resembling C. neglecta of the Niagaran, but differing in structural details. Pedicle valve less convex than brachial, with a pointed incurved beak. The valve is proportionally more convex at the beak, with the sides rather abruptly bending down. The valve broadens rapidly

Fig. 8 Camarotoechia hudsonica

forward, having a triangular appearance. Lateral slopes below the beak slightly concave, median depression beginning about halfway from the beak, at first faintly defined but becoming more pronounced toward the front, where it produces a marked deflection of the frontal margin. It is never very much accentuated, but contains three pronounced angular plications which toward the front are separated by interspaces nearly twice their width. A plication of similar strength limits the depression on each side, becoming progressively fainter outward. Thus there are from four to five medially depressed ones. At the beak the plications have the form of distinct threadlike, rounded striae. The concave lateral slopes are not plicate, but radiating striae have been observed in some specimens.

Brachial valve uniformly convex, convexity greater than that of pedicle valve. Beak closely incurved. In the center of the valve four angular plications become more elevated from the center forward, the central two being most elevated, rising at times so much above the others as to give the fold a biplicate aspect. On either side of these are two fainter ones, with, generally, indications of a third one near the margin. At the beak these plications are threadlike, rounded and uniform, except at the margin.

Surface of valves marked by very fine, threadlike concentric lines, which are elevated and are equally strong on the plications and interspaces. They are separated by spaces some

what exceeding them in width. These lines are not visible in exfoliated specimens.

This species is most nearly related to C. neglecta of the Niagaran of New York. It differs from that species in the more pronounced triangularity of the pedicle valve, the concavities on the lateral slopes below the beak, which give the valve somewhat the aspect of Rhynchotreta cuneata, the greater difference in convexity between the two valves and the fewer and less strongly pronounced lateral plications. The western representatives of C. neglecta have the median elevation and depression too pronounced, and the plications too sharp to correspond with our species, though the form and relative convexity of the pedicle valve are more nearly like that of the present species. On the whole, the two species are readily distinguished.

This species is abundantly represented in the upper Stromatopora bed of the Manlius limestone at Becraft mountain.

In the collection in the American Museum of Natural History containing some of the typical Coralline limestone fossils from Schoharie N. Y. this species is represented by a type more nearly like C. neglecta of the New York Niagaran. This has recently been described by Schuchert[1] as Rhynchonella litchfieldensis. The type specimen[2] erroneously figured as Atrypa lamellata, differs from our species as follows. The valves are more equally convex, the pedicle valve is less sharply constricted below the beak making the appearance less triangular. The median depression is faint, except near the front. It contains three plications which are like those of C. hudsonica. The character of the plications in general is like that of C. hudsonica, but there are about nine or 10 on each side of the depression, the outer ones fine but sharp. On the brachial valve of the four central elevated plications the median two are somewhat more raised. The number of lateral plications on each side is 10, the outermost fine and short.

[1] Am. Geol. 1903. 31:67.

[2] Palaeontology of New York, v.2, pl.74, fig. 11h and i.

Width 10 mm, hight 9 mm, thickness 6 mm. [Am. Mus. cat. no. $\frac{1543}{4}$] This compares quite well with a typical C. neglecta from the Niagaran of Lockport[1] except that the Lockport specimen has only six lateral plications on the pedicle and five on the brachial valve on each side. It differs as widely from the ordinary specimens of C. neglecta as does C. hudsonica.

Rhynchospira excavata sp.nov.

General form and proportions as in R. formosa Hall, of the Helderbergian. The present species is however very convex in the umbonal region, and the cardinal slopes of both valves strongly excavated, a feature which recalls more nearly Camarotoechia than Rhynchospira. The beak of the pedicle valve is strongly incurved over that of the brachial. The apical portion is broken away in the only specimen known so far. The posterior lateral margins of the pedicle valve have a gently concave outline to almost the middle of the valve, beyond which they round regularly to the front. In the brachial valve the posterior lateral margins form a nearly straight line.

A shallow median depression begins at the beak of the pedicle valve and gradually widens forward, having in each stage of growth about twice the width of the spaces between the plications. The bottom of the depression is rounded, becoming flatter toward the front. It is margined on each side by a plication, which is somewhat weaker than those covering the remainder of the shell. The latter are sharply rounded and at intervals appear subnodose in the exfoliated shell, this feature being caused by strong concentric striae. There are in all nine plications on each side of the median line; two of these are very faint and short and occupy the depressed cardinal slopes. In the brachial valve a faint plication marks the center and corresponds to the depression of the pedicle valve. On each side of this are seven plications, the interspace

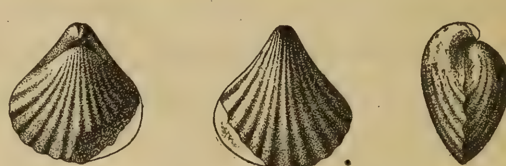

Fig. 9 Rhynchospira excavata

[1] Palaeontology of New York, v. 2, pl. 57, fig 1h, l, o; Am. Mus. $\frac{1543}{8}$.

between the first two plications being narrower than the three interspaces next succeeding. The seventh plication margins the cardinal slope, on which the eighth plication (corresponding to the interspace between the eighth and ninth plication of the pedicle valve) is undeveloped.

A single specimen was obtained by the Columbia University field party from the upper Manlius of Mount Bob. The exact position of the specimen was not noted, but it probably belongs to the horizon of the upper Stromatopora beds of Becraft mountain.

Whitfieldella cf. nitida Hall

A single crushed specimen has the characters of the larger individuals of this species. The greatest width appears to have been below the middle, the shell in this respect approaching W. intermedia in form.

A consideration of this very meager fauna, which here occupies the very summit bed of the Manlius, shows its affinity to be with the Cobleskill limestone of Schoharie and the bullhead waterlime of Buffalo.[1] That it is a somewhat more advanced fauna than that of the Cobleskill is shown by the fact that the more specialized S. eriensis is the predominating type. The affinity of the fauna with that of the Tentaculite beds of the Manlius is shown by the occurrence of S. vanuxemi.

Fig. 10 Whitfieldella cf. nitida

Second and third Stromatopora beds. Two feet below the upper Stromatopora bed is another about a foot thick but less continuous than the first. The intervening beds are rather shaly. The Stromatoporas in this second bed are fragmentary, having been broken and worn to some extent before they were embedded. Where the Stromatopora fragments are wanting, the rock is typical Manlius limestone with Leperditia alta. The Stromatopora appears to be the same as that in the upper bed.

[1] Hartnagel has shown the probable equivalence and continuity of the latter horizon with the Coralline or Cobleskill limestone of eastern New York. (J. M. C.)

Ten feet lower, or from 12 to 13 feet below the base of the upper Stromatopora bed, is a third one, averaging 2 feet in thickness. This has the aspect of a curly or concretionary rock, is of a darker color than the inclosing Manlius, and often highly crystalline. The structure of the Stromatopora appears on weathered faces only. The bed occasionally thins and then swells out again but does not exceed 2 feet in thickness. Its lower and upper contact surfaces are very irregular, and a certain amount of erosion (probably contemporaneous) appears to have occurred before the deposition of this bed. This is indicated by the wedging out of a 2 foot bed of Manlius limestone just below the bed, as shown in the annexed figure.

Fig. 11 Diagram of part of Stromatopora bed in city quarry, Hudson, showing the thinning out of the limestone layer beneath it

Both the lower and middle Stromatopora beds and the intervening rock are fissured and veined with calcite, which is often coarsely crystalline. A certain amount of slickensiding has also occurred, showing slight readjustment of the strata.

In the southern end of the quarry over 40 feet of the Manlius were at one time exposed without reaching the "Hudson river."

Contacts between Manlius and Coeymans. The contact between the Manlius and Coeymans, or the Siluro-Devonic contact, is shown in numerous exposures on the mountain. From the exposure at the head of the aqueduct in Greenport it can be traced westward for a short distance, when it disappears under drift. Scattered ledges of both upper and lower rock allow its approximate determination to the city quarry, where, as noted, it is again well shown. Beyond that it is traceable southwestward and southward in the cliffs and on the slope of the hillside, with some intermittances, though seldom with a well exposed contact, to the Jonesburg road. On the south edge of this, after crossing the meadow land, and halfway up the hill in a low cliff on the right, is a good exposure of the upper Manlius beds with the capping Stromatopora layer. The Coeymans is exposed in the road a short distance up the hill. The dip of the strata is 11°s.e., the strike n. 30°e. For some distance southward from this

point the contact is not well exposed, but it soon appears again in the cliff, which sweeps out toward the Ancram road, and faces it for over a mile to the high bluff at fault 21. All along this side of the mountain, the Manlius, from its fine and uniform texture and the perfect jointage developed in it, produces generally a vertical cliff. The Coeymans decomposes and makes more or less steeply sloping surfaces, which are generally used for grazing. The ledges project every now and then, making the slopes unfit for cultivation. In some places the upper part of the cliff is formed by the lower Coeymans, and at such points the bluff stands out boldly and is of great hight.

The contact may be conveniently studied along the wood road which leads across the middle of the mountain, and branches off from the Ancram road a little over half a mile south of the cross road at Jonesburg. Where this road ascends through a little ravine, the cliff on the left contains from 10 to 20 feet of Coeymans in the upper portion of its face, behind which the remainder of the Coeymans forms a slope to the foot of the cliffs formed by the New Scotland. Only the upper portion of the Manlius is well exposed along the cross mountain road. It is compact and finely stratified and contains Leperditia alta in its upper portion.

On both sides of the valley, bounded by faults 21 and 20, the contact between the Manlius and Coeymans is well exposed in the face of the cliff. No Stromatopora beds have been observed. Since, however, the actual contact can be seen only in a few points, owing to the steepness of the cliffs, it is not possible to say whether this bed is absent over the entire western face of the mountain or not.

Near the junction of the Ancram road with the southern road, the Manlius passes below the surface and does not appear again till the schoolhouse, half a mile farther east, is reached. Here the Manlius is seen just south of the road, standing vertically, the contact with the Coeymans, though not exposed, being close to the southern margin of the road. Just east of this, fault 18 has thrown the contact 600 feet to the south, the dip of the strata being still vertical or steeply inclined. From this point

eastward rocks are exposed within a few feet of the contact, so that the latter can be readily traced, with some interruptions, to a few hundred feet beyond the central mountain (Newman) road, after which no exposures of the Manlius have been observed for over half a mile northeastward. Hence the actual contact of the Manlius and Coeymans can not be determined, but it can be readily inferred from the positions of the contacts of the higher formations. Beyond this the contact can be easily ascertained, being for the most part actually exposed in the face of the cliff, or at least indicated by rock exposures within a few feet on each side of the actual contact.

The Stromatopora bed has not been observed along the eastern face of the mountain, but is found in the outcrops along the southern portion.

For the most part the outcrops of the Manlius appear as a narrow strip on the map. This is due to the fact that this formation, when but slightly inclined, generally makes a cliff, owing to the uniformly compact character and perfect jointing of the rock. When vertical or steeply inclined, a cliff may or may not be formed; in any case the exposure does not much exceed in width the thickness of the Manlius as found at Becraft. Only along the northern end a broad belt of this rock is exposed, for here the inclination is very gentle (10° to 20°), while the slope is likewise a gentle one and for the most part drift-covered. The absence of the usual cliff here may be accounted for by glacial erosion, this being the side most exposed to the force of the ice.

4 THE COEYMANS LIMESTONE

This is a compact, finely crystalline, generally dark colored limestone. Fossils are abundant only in the upper layers, the most characteristic species being Atrypa reticularis, Gypidula galeata and crinoid stems. Layers of chert are not infrequent, and in some outcrops form a constant and characteristic feature. There is sufficient argillaceous matter in this rock to give it the characteristic odor when breathed on. The organic fragments are large enough to be recognizable, though there is also a considerable admixture of flourlike

material. On the whole, the rock may be considered an argillaceous calcarenite.[1]

The rock is readily distinguished from the Becraft limestone by its texture and color, but not so readily from the Port Ewen.

The total thickness of the Coeymans is about 45 feet. The lower 20 or 25 of these are generally massive bedded, often crinoidal, and form commonly a vertical cliff in conjunction with the underlying Manlius limestone. The upper portion of the Coeymans is thinner bedded, with more or less shaly layers separating the beds, and this is expressed in the topography by a sloping bank, with occasional low, reeflike rock ridges marking the strike of the strata. This feature is most readily observed on the west side of the mountain, at the top of the cliff facing the Ancram road between Jonesburg and fault 21. The fossils are most abundant in this upper shaly portion, and to some degree these beds form a transition to the New Scotland above. Atrypa reticularis is everywhere common, while Gypidula galeata is also frequent in these beds. With these in the upper layers occurs rarely Spirifer macropleurus, showing the beginning of the New Scotland fauna.

The following is a list of the fossils of the Coeymans limestone of Becraft mountain, obtained chiefly from the upper beds.

1 Monotrypa tabulata (Hall). Not very common.

2 Favosites helderbergiae Hall. Several specimens were found in the top beds of this limestone. Some specimens were also found in the lowest beds.

3 Enterolasma strictum (Hall). Not uncommon in the upper beds.

4 Fistulipora torta Hall. Abundant.

5 Roemerella grandis (Hall). A specimen having the size and form of this species. The surface is covered with very irregular concentric striae, and extremely fine radiating lines are visible only between the concentric striae.

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[1] Grabau. Science, n. ser. Feb. 20, 1903. p. 297.

6 Lingula rectilatera Hall. A single specimen showing form and convexity of this species.

7 Dalmanella subcarinata Hall. A single specimen.

8 D. perelegans Hall. Occurring with Gypidula galeata.

9 Leptaena rhomboidalis (Wilckens). Abundant.

10 Stropheodonta varistriata Conrad, var. arata Hall. Not an uncommon form.

11 S. varistriata var. A specimen between the species and the variety arata.

12 Strophonella headleyana Hall. A specimen in the crystalline limestone with the features of this species.

13 S. leavenworthana Hall. 2 specimens.

14 Cyrtia dalmani Hall. 1 specimen.

15 Strophonella punctulifera (Conrad). Several specimens.

16 Spirifer perlamellosus Hall. A number of specimens showing variation in length and width and occurring in the more shaly or transition portion of the upper Coeymans.

17 S. cyclopterus Hall. Several specimens referred to this species.

18 S. macropleura Conrad. In the calcareous portion of the upper Coeymans, i. e. the transition beds, a specimen was found showing the characteristic features; with it occurs Gypidula galeata.

19 Uncinulus nucleolatus (Hall). A single specimen.

20 Eatonia peculiaris Conrad. A perfect specimen.

21 E. medialis Conrad. Rare but typical.

22 Atrypa reticularis (Linné). Common.

23 Gypidula galeata (Conrad). Abundant.

24 Anastrophia verneuili Hall. A single characteristic specimen from the upper part of the limestone.

25 Meristella princeps Hall. A single large brachial valve.

26 Pterinea (?) textilis (Hall). 1 specimen.

27 Platyceras platystoma Hall. A specimen with the general aspect of this species.

28 P. subnodosum Hall. 1 specimen.

29 P. cf. retrorsum Hall. 2 specimens agreeing in general with this species.

30 P. unguiforme ? Hall. 2 specimens having the form of this species, but lacking the full number of plications.

31 Dalmanites micrurus (Green). Rare.

32 D. cf. pleuroptyx (Green).

33 Phacops logani Hall. A head in the fine compact limestone, probably the transition beds of the Coeymans. With it occurs Gypidula galeata and Monotrypa.

The following species were obtained mainly from the upper layers of the Coeymans at Mount Bob.

1 Favosites helderbergiae. Basal beds.

2 Rhipidomella cf. oblata Hall.

3 Stropheodonta varistriata (Conrad). Associated with Uncinulus pyramidatus in the crystalline limestone.

4 S. varistriata var. arata Hall.

5 Spirifer cf. saffordi Hall. 2 specimens with the characters of this species.

6 S. perlamellosus Hall. 1 specimen.

7 S. cf. octoplicata Hall. With no. 13.

8 Uncinulus pyramidatus (Hall). With 3, 12, 13 and 15.

9 U. cf. mutabilis (Hall). Young; 2 specimens.

10 Rhynchospira formosa Hall. 2 specimens.

11 Rhynchonella altiplicata Hall. With 14.

12 Meristella princeps Hall.

13 M. laevis Hall. 1 specimen.

14 Gypidula galeata. Common.

15 Aviculopecten spinulifer (?) Meek & Worthen. A specimen of a right valve more convex than that figured by Hall, but showing form and surface characters of that species.

16 Dalmanites cf. micrurus Conrad.

From these lists it will be seen that a considerable number of species commonly referred to the next fauna, i. e. the New Scotland, are found in the upper Coeymans. In these same beds Gypidula galeata is common, thus showing well their transitional character.

All of this series contains crystalline limestone, while the overlying New Scotland contains no pure limestone. The finely crystalline character of the Coeymans also distinguishes it readily from the Manlius, which is generally compact. About the middle of the eastern face of the mountain, where the beds are all on end, the thickness of the Coeymans measured across the strike is 42 feet. [See *postea*]

The most accessible exposure of the lower and upper contacts of the Coeymans is on the middle transverse mountain road leading off the Ancram road a short distance south of the old glue factory. One of the best places to obtain the fossils of this rock is at the extreme southwest corner of the mountain on the north side of the road leading southeast. The rock here is exposed at the road side.

5 NEW SCOTLAND SHALES

These are thin bedded, argillaceous to silicious rocks, in which a variable amount of calcium carbonate is present. Usually this is insufficient to allow the rock to be affected by acids, there being no, or but very feeble, reaction on applying strong HCl. Fossils are abundant but usually only preserved as molds, though, when the rock is freshly broken, the shell is still found remaining.

The following list comprises the species obtained from these beds at Becraft mountain.

1 Enterolasma strictum Hall.

2 Rhipidomella tubulostriata Hall. Rare.

3 R. eminens Hall. Several.

4 R. oblata Hall. Several.

5 Dalmanella perelegans? Hall.

6 D. cf. subcarinata Hall. Rare.

7 Schizophoria cf. multistriata Hall. A specimen showing form, convexity and striae of this species.

8 Orthothetes radiatus Fischer. Rare.

9 O. woolworthanus Hall. Common.

10 Stropheodonta becki Hall. Common.

11 Strophonella headleyana Hall. Common.

12 Leptaena rhomboidalis (Wilckens). Common.

13 Spirifer macropleura (Conrad). Common.

14 S. perlamellosus Hall. Common.

15 Eatonia peculiaris Conrad. Rare.

16 E. medialis Vanuxem. Frequent.

17 Meristella cf. arcuata Hall. Rare.

18 M. subquadrata Hall. Rare.

19 Anastrophia verneuili Hall. Rare.

20 Diaphorostoma ventricosum (Conrad). Large individuals.

21 Platyceras bisulcatum Hall.

22 P. ventricosum Conrad.

23 P. gebhardi Conrad.

24 Platyceras sp. Several uncoiled forms which represent the next stage after P. gebhardi cf. P. magnificum of the Oriskany.

25 Dalmanites micrurus Green. Frequent.

26 D. nasutus Conrad. Frequent.

27 D. pleuroptyx? Green. A single specimen, somewhat distorted by cleavage across the bed, lying in such a position that the compression shortened and widened it.

In the quarry face of the Jonesburg stone-crusher, about 25 feet of the New Scotland beds are exposed. They are quite calcareous and heavy bedded where freshly broken. In the lower portion the characteristic fossils are common, i. e. Spirifer macropleura, Strophonella headleyana, Stropheodonta becki, Leptaena rhomboidalis, etc.

The best measurement obtained of the thickness of the New Scotland was 68 feet. This was taken just north of fault 14 where the whole formation is exposed on end between the Coeymans and the Becraft limestones. On the hillside above fault 21, the measured thickness was 70 feet to 75 feet. Wherever these beds are but slightly inclined, they form a series

of steps in the topography, with a steep cliff due to the well developed joint planes, and a gentle slope down the bedding plane. Not infrequently a number of such steps are met with in crossing the outcrop from the Coeymans contact to that of the Becraft above. These may vary in hight from a few feet to 30 or more feet, but generally they range between 10 feet and 20 feet in hight. It is this steplike arrangement which caused Mather to believe in the existence of block faulting [fig. 1, p. 1031].

The New Scotland is the boulder formation of the region. Blocks of it are found everywhere scattered over the fields, or piled up in fences. Along the eastern side of the great Oriskany "bottom" on the western half of the mountain, a wall of these blocks occurs. though there is no outcrop nearer than half a mile. Near the middle transverse mountain road, these bottoms are strewn with boulders of New Scotland, which also are abundant on the side of the Esopus hill east of the bottom. These fragments might easily mislead one to look for an outcrop of the New Scotland in this locality.

6 BECRAFT LIMESTONE

This is a light gray, coarsely crystalline limestone (calcarenite) becoming in places a shell marble. Certain beds, specially near the bottom, are composed of crinoid joints, and the basal portion of the calyx of Aspidocrinus scutelliformis, while near the top shells of Gypidula pseudogaleata locally make up the rock. The fossils, though numerous, are not very rich in variety. The most abundant and characteristic types are Spirifer concinnus, usually small, Gypidula pseudogaleata, Atrypa reticularis and Uncinulus campbellanus. The following is an annotated list of the species found in this rock.

1 Fenestella sp.

2 Schizophoria multistriata Hall. Not very common.

3 Leptaena rhomboidalis (Wilckens).

4 Spirifer concinnus Hall. Small individuals with the character of the young of this species are common in the limestone. The sinus of these specimens is angular, and there

are five or more plications on each side. An average individual measures 11 by 15 mm and has about six or seven plications on each side of the median sinus. A larger individual measures 18 by 26 mm and shows the characteristic high area and sloping cardinal sides of this species. It has about 10 plications on each side of the sinus. This is the most characteristic species of this limestone, but most of the individuals are small, with immature characters.

5 Spirifer perlamellosus Hall. Several specimens showing characteristic form and plications but only occasionally showing the concentric lamellae.

6 S. cyclopterus Hall. A few specimens showing form and character of plications of this species.

7 Rhynchospira formosa Hall. 2 well marked individuals.

8 Uncinulus campbellanus (Hall). A common species in this limestone.

9 U. nobilis Hall. A number of more rounded and more coarsely plicate individuals from these beds are referred to this species. They do not have the characteristic lateral depression of the cardinal margins.

10 Atrypa reticularis (Linnè). A robust variety is common.

11 Meristella princeps Hall. A single specimen.

12 M. arcuata Hall. Several internal molds and a shell with the characters of this species.

13 Eatonia medialis Vanuxem. A single valve referred doubtfully to this species.

14 Trematospira perforata Hall. A single characteristic specimen of this species was obtained from the weathered portion of this limestone.

15 Gypidula pseudogaleata Hall. Abundant.

16 Rensselaeria mutabilis Hall. A single specimen.

17 Platyceras cf. gibbosum Hall. This specimen may have come from the New Scotland layers.

18 Aspidocrinus scutelliformis Hall. Abundant in the lower layers of the limestone.

The following species were obtained from the top layers of the Becraft limestone:

1 Monotrypa sphaerica (Hall)
2 Leptaena rhomboidalis (Wilckens)
3 Spirifer concinnus Hall
4 Rhynchospira formosa Hall
5 Eatonia medialis Vanuxem
6 Gypidula pseudogaleata Hall
7 Spirifer sp.

These form a transition to the Port Ewen fauna.

Just above the stone-crusher quarry at Jonesburg an excavation in the hillside shows the basal members of the Becraft. The beds here are 6 inches to a foot in thickness, and separated by shaly layers. The dip is 11° into the hill; the actual contact is not exposed however. In the old Fred W. Jones quarry, nearly the full thickness of the Becraft is shown in the quarry face opposite the junction of the quarry road with the Jonesburg cross road. About 6 or 8 feet of the lower beds are concealed, which, together with the thickness exposed in the cliff, about 35 feet, make a total thickness of between 40 and 45 feet for the Becraft limestone. The Port Ewen appears a short distance south of the edge of the quarry, the surface slope here being with the dip of the strata. Hence the above estimate of the thickness is very close. A similar thickness of 45 feet was obtained by measurement of the outcrop on the east side of the mountain, where the strata stand vertically. The limestone has been extensively quarried in the past for flux, the amount of $Ca\ Co_3$ being nearly 92%. The following analyses were published by Ries in his report, the *Limestones of New York and their Economic Value*.[1]

	1	2
Lime	51.4	......
Lime carbonate	......	91.7
Carbon dioxid	49.191	......
Magnesium carbonate	......	3.51
Magnesia	2.233	......

[1] N. Y. State Geol. 17th An. Rep't 1897; N. Y. State Mus. 51st An. Rep't, 2:431.

	1	2
Alumina	.635	1.01
Ferric oxid	1.819	.55
Silica	1.842	1.89
Sulfur dioxid	.145	.049
Phosphorus	.149	.022
Water	.271	......
	107.685	98.731

7 PORT EWEN (KINGSTON) BEDS

In his sections of the region about Kingston and Rondout Davis[1] described a series of shaly limestones, lying above the Becraft limestone, and similar in character and fossil content to the Shaly limestones (New Scotland beds) underlying the Becraft. To these upper beds Davis gave the name of Upper Shaly limestone which was later on changed to Kingston beds by Clarke & Schuchert.[2] This term was, however, preoccupied by various authors for formations of Precambric, of Siluric and of Pleistocenic age, and Clarke has since proposed the name Port Ewen beds, from the town opposite Rondout, near which these beds are best exposed.

The thickness of these beds near Port Ewen station on the West Shore Railroad is recorded as 222 feet. Van Ingen and Ruedemann divided them into 18 subdivisions and made extensive collections from these, which have been published by Clarke.[3] On the authority of these collections, Clarke states that "the fossils of all its layers are those of the true New Scotland limestone faunas, the contents of the higher layers varying little from those of the lower." As no such formation seemed to occur at Becraft mountain, where the normal succession of strata is undisturbed and clearly exposed, I visited Rondout hill in company with Dr John C. Smock, in order to study the formation at the type locality. Accompanied by Mr P. E. Clark, the mining engineer of the cement works, I made a careful examination of critical points on the hill, expecting to find the lower Shaly beds

[1] Am. Jour. Sci. 1883. 26:389.

[2] Science. Dec. 15, 1899.

[3] Oriskany Fauna of Becraft mountain, p. 73.

repeated by overthrust faulting. Above the Becraft limestone and below the beds pointed out by Mr Clark as "Upper Shaly," and so mapped by Davis and Darton, the Coeymans limestone was found in full force with characteristic Gypidula galeata and Atrypa reticularis, as well as the chert beds characterizing it as Becraft. Above the "Upper Shaly," after careful search in the woods, the typical Becraft limestone was found, which in turn was overlain by a darker, fine grained limestone identical in character with the beds lying between the Becraft and Oriskany at Becraft mountain. Above this was found the Oriskany. On extending our observations, Mr Clark pointed out a spot where the Becraft, inclined about 50°, was quarried below, and the Rondout waterlime, inclined at 42°, was quarried above it. On examining the contact between the limestones below the point where the Coeymans was found overlying the Becraft, in the roof of an old quarry in the latter rock, it was found that the line of supposed overthrust was clearly marked by extensive slickensiding of the adjoining strata.[1]

A subsequent visit to this hill in company with Dr Ruedemann showed the essential correctness of the interpretation of the structure, but it was found that the thickness of the beds lying between the Becraft and the Oriskany was greater than at first supposed, Dr Ruedemann measuring 110 feet.

A visit to the section in the West Shore Railroad showed a great thickness of the Upper Shaly beds between the Becraft and the Oriskany. The section made by the railroad however is, as pointed out by Mr Clark, a diagonal one and numerous small faults occur in it so that the actual thickness would be less than 222 feet, as recorded by Clark. Since the interval between the Becraft and the Oriskany can be readily measured on Rondout hill, though the beds occupying that interval are poorly exposed, it

[1] No "Upper Shaly" beds are recorded by Davis in his sections and descriptions of the "Little mountain region" east of the Catskills. His map covers an area of about 10 miles in length and throughout this the Oriskany, where present, rests directly on the 120 feet of limestone which he referred to the Upper Pentamerus (Becraft). The upper part of these undoubtedly represents the Port Ewen of Becraft.

seems probable that the Port Ewen section, which is not more than a mile and a half south of the former, contains not much more of these beds. Darton estimates the thickness as 125 feet in the central and southern portion of Ulster county, and states that it decreases northward to 30 or 35 feet in the Saugerties region, near the Greene county line.[1] The Upper Shaly beds of the Port Ewen section have a thickness of from 100 to 200 feet, but except along the roadside, they are poorly exposed on Kingston hill. They, together with the Becraft and the repeated Lower Shaly, were mapped by Davis and Darton as Upper Shaly, while the characteristic fossils cited by these observers were obtained beyond doubt from the repeated Lower Shaly beds, for Spirifer macropleura and Orthothetes radiatus cited by Davis and Darton as characteristic of the Upper Shaly do not appear in Clarke's list of these beds as exposed in the Port Ewen section.

At Becraft mountain these beds are well shown. They are dark crystalline limestones recalling the Coeymans limestone. They crop out in a series of steps with a total thickness of not over 25 feet. They are particularly characterized by the Monticuliporoid Monotrypella tabulata, which may be easily recognized by the transversely wrinkled aspect of the corallites. This species is however not restricted to this horizon, being also known in the Coeymans limestone.

The best exposures of the Port Ewen beds are along the quarry road from the old Jones quarries to the transverse mountain road. Here the thickness can be best determined, and the characteristic fossils obtained. The bluffs here rise up to 15 or 20 feet in hight, and above them there is a continuous slope eastward, conformable to the dip of the strata, to a low swampy meadow, where fragments of Oriskany limestone indicate that the contact is near. Allowing for a slight addition above, and a similar addition below to the contact with the Becraft, I do not think that the total thickness of the Port Ewen at Becraft mountain will exceed 25 feet.

[1] N. Y. State Geol. 13th An. Rep't. 1894. p. 304.

In lithic character the Port Ewen beds of Becraft resemble the Coeymans, and, like these beds, they contain more or less chert. The similarity is emphasized by the occurrence of Monotrypella tabulata in both.

The paleontology of this limestone still needs a careful study. The following annotated list represents the species found in a brief examination of this rock during the progress of mapping the contacts. Care was taken to obtain them from characteristic outcrops, so that there could be no confusion with overlying or underlying strata.

Fossils of the Port Ewen beds of Becraft mountain

1 Monotrypella tabulata (Hall). Abundant, particularly in the upper beds.

2 Cladopora cf. styphelia Clarke. 2 specimens which resemble this species, but have smaller apertures at intervals surrounding, or nearly so, the larger; found in the upper beds.

3 Orthothetes becraftensis Clarke. A few specimens of this Oriskany species were found showing characteristic form and surface markings.

4 Leptaena rhomboidalis (Wilckens). Middle beds.

5 Stropheodonta sp.

6 S. (Leptostrophia) magnifica Hall. In the middle Kingston beds are some specimens which may readily be referred to this species. The muscular scar is less sharply marked than in Str. becki, they are larger and more spreading, and there are four stronger diverging ridges on each side of the central one. The punctate structure is well marked, the punctae being disposed in rows between the striae. No concentric wrinkles have been seen in any of these specimens. These specimens appear to be intermediate between S. becki and true S. magnifica. A large typical pedicle valve, having a maximum width of nearly 75 mm, was obtained from the lower beds just overlying the typical Becraft. A moderate sized specimen was obtained from the upper beds.

7 Spirifer concinnus Hall. A large pedicle valve, with a width of 40 mm and a hight of 25 mm, was obtained from

the middle beds; the width of the sinus at the anterior margin is 10 mm, and there are 13 or 14 plications on each side of the sinus.

8 S. concinnus Hall. Small specimens like those found in the Becraft beds are not uncommon in the middle beds on the quarry road.

9 S. cyclopterus Hall. A large specimen was obtained from the middle beds on the quarry road.

10 S. sp.

11 S. perlamellosus Hall. Middle beds; rare.

12 Rhynchospira formosa Hall. 1 specimen.

13 Eatonia peculiaris Conrad. Middle beds; rare.

14 Meristella typus Hall. A single specimen showing form and concave or flattened cardinal margins of this species, was found in the upper beds. According to Schuchert this species occurs only in the Manlius of Cumberland Md.

15 M. cf. princeps Hall. Middle beds.

16 M. sp.

17 Rensselaeria sp.

18 Platyceras cf. trilobatum Hall. Middle beds.

A consideration of this list shows that these beds have a transitional character from the Becraft to the Oriskany of Becraft mountain. This is shown by the occurrence of characteristic Oriskany and Becraft species side by side as well as by the intermediate character of some species.

Oriskany species are Cladopora styphelia, Orthothetes becraftensis, Stropheodonta magnifica and Eatonia peculiaris. Affinities with the Becraft limestone are shown by Spirifer concinnus and with that and the lower beds by S. cyclopterus, S. perlamellosus, Rhynchotrema formosa, etc.

A more extended collection would probably show more transitional forms in the lower and middle, and other Oriskany species in the upper beds.

8 ORISKANY BEDS

These are silicious limestones, often with an abundance of chert, the fossils being mostly silicified and weathering out readily. Says Clarke:[1]

These strata, highly silicious, hard, dark limestones, have been most favorably exposed to decomposition, and in consequence the calcareous matter has been largely leached out for a considerable depth on all exposed surfaces, only a porous residuum remaining. This light, rusty and firm rotten stone retains the external and internal casts [molds] of the fossil remains with which it is filled, in exquisite detail and forms excellent material for study. Only by hastening nature's process with acid can the fossils be made out from the black and cherty or unchanged calcareous cores of this rock.

The fauna of this formation was fully described and illustrated by Clarke. He summarizes it as follows:[2]

Of the 94 clearly defined species of this fauna, 38 represent expressions of species which began their existence in Helderbergian times; on the other hand, but 18 of the species of the fauna continued their existence, or appear to be represented by closely allied forms beyond the close of the Oriskany sedimentation. 29 are represented in the earlier known fauna of the arenaceous beds of the Oriskany.

The only satisfactory exposures of the Oriskany bed *in situ* are, first, on the middle mountain road (Newman road) along the western side of the road between the quarries of Becraft limestone on the north and the stream which crosses the road near the contact of the Oriskany and Esopus on the south; and second, in the field to the east of this, where the beds are brought up in little folds. The best collecting grounds for the weathered out fossils are in this same field, north of the flat bottomed meadow ground, and in the fields west of the swampy area which marks the Oriskany-Esopus contact on the western side of the mountain. One of the most accessible localities is at the crossing of the middle transverse mountain road over this stream. Weathered out Oriskany fossils are also found at the northern outcrop of the Oriskany on syncline no. 2 and occasionally along the stream following the Oriskany outcrop between faults 15 and 17. The

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[1] Oriskany Fauna of Becraft Mountain, p. 12, 13.

[2] *Loc. cit.* p. 71.

rock with its fossils weathered out in relief is seen in a little hillock in the southwestern part of the mountain, where it has been brought up by fault no. 19. [See map]

It is not possible to give the exact thickness of this formation at Becraft. It can not be more than a few feet, and is probably not much more than a foot. It grades below into the Port Ewen limestone, but is abruptly overlain by the Esopus grits. The contact between the Oriskany and Esopus is everywhere marked by low swampy ground and by the existence of stream beds. A glance at the map will show that the streams have all become adjusted to the Oriskany bed, not so much because this rock is a softer one, for, though commonly decomposed, the silicious portion stands out in relief. It is rather due to the fact that the overlying Esopus shales break up readily into a fine gravelly soil, which is easily removed by the streams. The Oriskany and Port Ewen act as a guiding plane along which the streams work downward. The few departures from the characteristic method are explainable by local conditions of folding or faulting.

9 and 10 ESOPUS AND SCHOHARIE GRITS

These are dark chocolate-colored, gritty shales, with a combined thickness of about 300 feet, of which about one third is considered as belonging to the Esopus. The dividing line is drawn on lithic characters, which are chiefly expressed in topographic features. The Esopus readily crumbles into small cubical fragments under the influence of the weather, and hence presents rolling surfaces, which commonly constitute the best farming ground of the region. The Schoharie, on the other hand, resists the weather more easily, but generally has its cleavage planes well developed by the weather. These are commonly at a high angle, and their presence obliterates the original bedding planes. The topography of this rock is rugged, with numerous ledges, and hence is generally left wooded. The best exposure of the Esopus is above the contact line with the Oriskany on the west side of the mountain. Here in the hillside above the stream, ledges of the Esopus are visible. The Schoharie may be studied almost anywhere over the area of its outcrop. Clarke has recorded the

following species from the outcrop of the Schoharie at the junction of the Newman road with the middle transverse mountain road.[1]

Dalmanites anchiops, Phacops cf. bombifrons, Coelospira cf. camilla and Chonetes cf. arcuatus. These he considers sufficient to identify the ages of the beds.

11 ONONDAGA LIMESTONE

This is the highest formation of Becraft mountain. It occupies the top of a ridge in the southeastern portion of the mountain and is of very limited extent. The portion of the bed remaining is involved in syncline no. 2, the eastern limb of which is turned up vertically. The upper part of the rock is very cherty and weathers with irregular surfaces. The limestone is light gray in color and finely crystalline. Fossils are not readily found, but Clarke has recorded Spirifer raricosta and Zaphrentis from the upper part, and from the lower, chert-free beds Odontocephalus selenurus, Spirifer varicosus, Atrypa reticularis, Leptaena rhomboidalis, Streptorhynchus pandora, Chonophyllum, Zaphrentis, Favosites and Stromatopora or Fistulipora.[2] Orthoceras and Euomphalus were also noted in the upper beds.

The total thickness of the Onondaga is not over 25 feet and is probably nearer 20 feet.

The outcrops of this rock are most easily approached from the eastern road by striking into the fields after crossing the little stream from the Oriskany depression, which here breaks across the strata to join Claverack creek. It may also be approached from the Newman road by following the Oriskany depression northeastward and ascending the hill. The approach over the Schoharie is difficult on account of the wooded and rough character of the land.

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[1] *Loc. cit.* p.14.

[2] *Loc. cit.* p.15.

TECTONIC FEATURES

Becraft mountain is an isolated remnant of the Helderberg mountains and partakes of the general structure of the Appalachian system of which it forms a part. It is not the only remnant of the Helderbergs on the east of the Hudson river, for a few miles to the northeast lies Mount Bob, which is an abbreviated edition of Becraft having suffered all but complete destruction by erosion.

Whether Becraft mountain represents a fault block of the Helderbergs dropped down among the "Hudson river" strata and so preserved from erosion, or whether its low lying position with reference to the Hudson river beds surrounding it, is due to the fact that it forms an axis of a particularly deep syncline, which during the peneplenation of the surrounding country was too low to suffer erosion, is not easy to determine. Certainly, if the strata on the west of the mountain were continued upward at the same angle with which they now dip into the mountain, they would pass above the highest point of Mount Moreno, which is the highest mass of Hudson river strata lying between Becraft and the Helderbergs. The fact also that Mount Bob, lying in the direction of strike of the Becraft strata, has a synclinal structure, indicates that they are one and the same part of the low lying synclinorium.

The main synclinal axis (no. 1) of the Becraft mountain synclinorium runs about through the center of the mountain. The western limb is simple, but the eastern limb is strongly folded and faulted. Two anticlines (no. 1 and 2) and two more synclines (no. 2 and 3) are readily traceable over the eastern half of the mountain. The eastern limb of the third syncline (no. 3) forms the western limb of a third anticline (no. 3), this anticline being complete in only one locality [*see* sections 12-15], where it is followed eastward by another syncline (no. 4) and finally by a small symmetric anticline (no. 4). Besides these there are several minor folds between the major ones. The principal folds (anticlines 1, 2 and 3) are strongly asymmetric, their western limbs varying from steeply inclined through perpendicular to strongly overturned. In addition to this, the

eastern side of the mountain is strongly diversified by numerous faults. The axes of the folds approach each other toward the southwestern end of the mountain, where they are cut off by a transverse fault (no. 18). As might be expected, the folding is likewise more intense in this locality, as will be seen by a comparison of sections 21 and 25. The general pitch of the Becraft syncline is toward the southwest. But there is also a local pitch to the northeast in the strongly folded southwestern area. Thus a basin-shaped appearance is produced, with the successive rimming around of the outcrops of the lower about the higher strata.

The faulted district begins on the northeastern corner of the mountain. Here, as shown by the following section [section 3], the throw is comparatively slight. Fault no. 1 is a gravity fault the hade of which could not be accurately determined, but appears to be vertical; the strata are abruptly turned up at the downthrow side. This feature is very readily seen in the hillside. The amount of vertical displacement here is about 20 feet. Fault no. 2 is a thrust fault with a very oblique fault plane, the hade being about 70°. The vertical throw is from 70 to 80 feet and the horizontal displacement about 300 feet. From the fact that the fault is traced down the hillside, it appears curved on the map.

Fault no. 3 is a gravity fault, a block east of it having dropped down. It can be followed along a wood road in a depression, with the Coeymans on the east and the Manlius on the west of it, both dipping westward, the Manlius at a greater angle. The

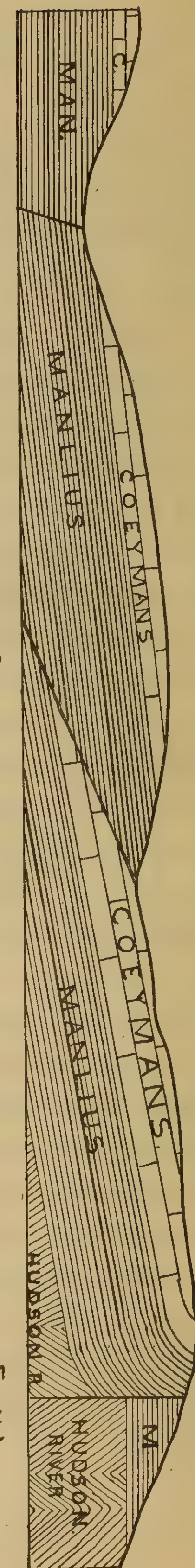

Fig. 12 Section of northeast portion of Becraft mountain, showing three faults

eastern face of the fault block is mainly a steep cliff, with the contact between the Manlius and Coeymans part way down the cliff. The Manlius is here much jointed, with vertical joints which on weathering give the aspect of vertical bedding. Shortly before reaching the bend in the wood road, where it leads off to the Becraft quarries, a sink hole of moderate depth is met with. There are several of these on Becraft, which point to a more or less cavernous condition of the low lying limestones. Faults 4 and 5 appear to bound the keystone of a small anticlinal fold, which has collapsed at the center. The strata on either side of the central fault block are dipping away from it. Fault no. 5 also permitted a lateral displacement of the blocks. South of fault no. 5 the surface rock is the Coeymans, which, together with the dip of the strata, would give about twice the known thickness of the Coeymans. It seems therefore highly probable that another fault (no. 6) runs through the center longitudinally. The throw is of course not so great in this second block, since no Manlius has been brought to light. Fault no. 6 must be regarded as the continuation of fault no. 3. Both of these faults are earlier in date than fault no. 5. Fault no. 7 is another gravity fault with the downthrow on the southeastern side, and the strata of this portion steeply turned up on the fault plane. West of this the strata are strongly folded, as shown in section 6.

Fault no. 8 is more of the nature of a breached anticlinal fold, though a slight displacement seems to have occurred at the axis of the fold, where a small stream runs from the mountain side. All of these displacements and extra folds die out toward the southwest, as shown in section 12a, where only a single fold (anticlinal 1) can be made out.

Unlike the preceding faults, which mostly had a uniform direction (about n. 40 e.) or else were parallel to the strike, fault no. 9 has a direction a little south of east. It cuts off the end of syncline no. 2, causing a partial repetition of some of its strata, i. e. Becraft and New Scotland. The downthrow in this case is on the north side of the fault.

South of this fault, the structure becomes more complicated. The eastern sharper and more closely crowded folds now appear, and with them a number of thrust as well as gravity faults. The structure of this area, as far as section 20, is shown on a larger scale on the section map, and will now be described in detail.

Just south of the point where Claverack creek strikes the eastern road, i. e. at fault no. 9, we meet with one of the numerous, more or less overgrown wood roads which lead up the mountain. Following this road, which leads off westward from the main road, we find, on turning at a bend, that we are following a depression along the strike of the strata. This depression marks the location of fault no. 10, a strike fault. To the west of this fault the strata dip 20° to 25° westward, while on the other side they dip as much or more to the east. The strike of the Manlius and the overlying Coeymans, east of the wood road, is at first nearly east and west, the dip being as high as 30° or 35° to the south. This is caused by fault no. 11, a short diagonal fault between 10 and 12. Between this shorter fault and the main strike fault (no. 10) a triangular surfaced block has been tilted to the degree indicated by the dip. As this block stands now, only the Coeymans and Manlius compose it. East of fault 11 the strata dip steeply to the southeast, the angle ranging from 50° to 75°, while the strike is n. 30° e. Nearly the entire thickness of the Coeymans is exposed three times in the region of these faults, as shown by section no. 7. The Manlius forms the eastern portion of the section, dipping, as far as exposed, about 60° to the southeast, thus showing a complete overturn of the strata, the Manlius resting on the Coeymans.

South of the triangular fault block the structure is somewhat simpler, being affected only by two longitudinal strike faults. The first (no. 10) brings the steeply eastward dipping New Scotland (70°, s. 60° e.) against the gently inclined westward dipping Coeymans (20°, n. 60° w.), as shown in sections 8, 9 and 10. To the west of the fault the beds from the Coeymans up are shown, while on the east of this fault, the New Scotland, Coeymans and Manlius are found in the reverse order, owing

to the overturning of the beds. A second longitudinal or strike fault (no. 12) begins in the Manlius on the northeast and a little later passes into the Coeymans [section 10] ending finally in a small diagonal fault. Thus once more eastward dipping beds are brought in contact with the steeply overturned strata, partially repeating the Manlius in the upper, and the Coeymans in the lower section (nos. 9 and 10).

A little farther southward, another triangular fault block occurs, bounded by faults 11, 13 and 14. The probable structure of this block is shown in section 10. On the east the overturned Manlius, Coeymans, New Scotland and Becraft are visible, all dipping very steeply to the southeast, some beds being almost or quite vertical. A low ridge of Becraft with the strata standing vertically, is succeeded westward by a flat valley [*see* section 11] in which no strata are exposed. This valley is bounded on the west by fault 10, beyond which is another ridge, on the summit of which the Becraft is again seen dipping 40° northwestward. No exposures are shown at the base of the ridge at this point, but it is almost certain that the New Scotland lies at its base and that it is merely a southward continuation of the same structural ridge found just northward, where the New Scotland is shown. The westward dipping strata are bounded on the east by fault 10, which has here turned more to the west. What strata occur between the fault and the low ridge of Becraft have not been ascertained, as no satisfactory exposures were noticed. Some rock masses which appeared to be in place, were finely crystalline, shattered and veined limestones, which may represent either the Coeymans or Port Ewen. No fossils were obtained, but from the character of the strata a little farther south [section 14], it appears most natural that the valley is occupied by a closed synclinal fold of Port Ewen, with possibly some Oriskany in the axis of the fold (which would account for the valley). The Becraft probably comes up again on the other side of the syncline, next to the fault. Fault 14 is followed by an old wood road, which leads down to the main road east of the mountain. South of this fault the Manlius forms the greater part of the surface. It

forms a synclinal trough, the axis of which dips 10° southward. The appearance of this portion of the surface is therefore something like half of a shallow basin. On the western side of the trough the rocks are sharply overturned, so that they dip 80° to the eastward, but with their uppermost side down. This overturn fold bounds a flat bottomed tract or longitudinal valley. On tracing the fold southwestward along the strike, it is found that less and less of the upper Manlius strata are uncovered in the axis of the fold; and that, finally, they are covered entirely by the Coeymans limestone. This again shows the southward pitch of the fold. As shown by the eastern ends of sections 14 and 15, the strata there are involved in another simple anticlinal fold (no. 4), which, from the southward pitch, is formed on the present surface by progressively higher and higher strata in that direction. The western boundary of the aforementioned longitudinal, flat bottomed depression [section 14] is formed by a double ridge of Becraft, the eastern portion of which dips 60° eastward, while in the western ridge the dips are 25° to 30° to the west. A little farther south [in section 15] only the westward dipping ridges of Becraft, capped by Port Ewen and underlain by New Scotland, occur. This shows that a fault line passes between the two sections. This fault is well marked to the southeastward, where the Manlius is thrust over the Coeymans. This overthrust fault is finely shown in the cliff facing the roadway along the eastern border of the mountain. Here the relations shown in the following diagram are clearly exhibited.

This overthrust fault appears to be earlier than, or at least contemporaneous with, the longitudinal strike faults (10 and 12), for the latter are not seen south of the overthrust fault. This fault may be traced northwestward as far as the little brook which drains the great meadow. Here it appears to pass into a strike fault and is not traceable any farther. As we go southward, the pitching axis of the fold reveals another fold as shown by the sections [15-20]. These folds are of the typical Appalachian type, with a steep, overturned limb on the west and a gentler, normal limb on the east. Eastward this eastern limb again passes under and rises as the steep or overturned western

limb of a second anticline. That this was another similar fold to the one discussed appears on comparing sections 14-20. It is highly probable that the western end of section 15, from the axis of the overturn fold now shown in the Coeymans near the middle of the section [A], was of the type of those of section 20.

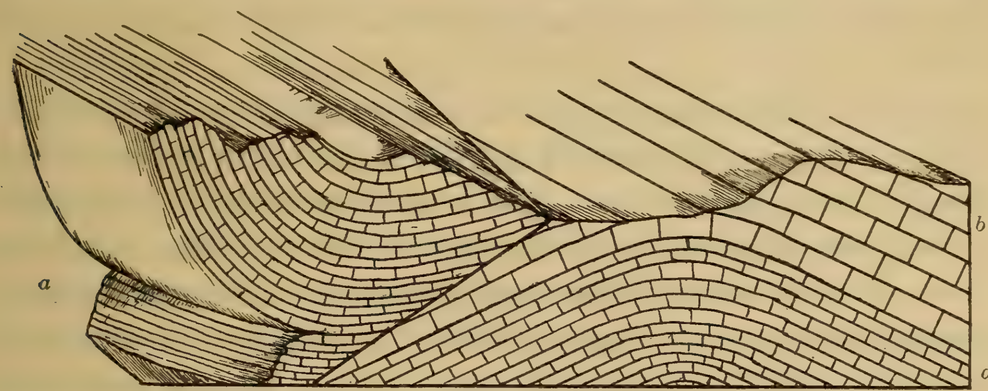

Fig. 13 Overthrust fault with infolded Manlius (*a*) and Coeymans (*b*)

If the latter section were added to the eastern half of section 15, so that the extreme eastern end of 20 [A] coincided with the axis of the overturn anticline [A, section 15] we would restore what appears to have been the normal type of folding of this region. Beginning on the east, there was a simple anticline with the limbs nearly equal. This was followed by a broad syncline, with a gentle westward dipping limb on the east and a more abruptly eastward dipping western limb. The latter formed the eastern limb of the overturned anticline, which had almost become an isocline. The strata came up again in a broad syncline with overturned eastern and low western limb, after which they were again involved in an overturn anticline of the same type as the preceding. A similar syncline to the last followed, and was in turn succeeded by a third overturned anticline in the Onondaga, as shown in section 21. The syncline following this is of the same type as the two preceding; its western limb, with an angle of 12° or 15° eastward dip, forms the western side of Becraft mountain. We may safely assume that three close overturned anticlines existed, besides the apparently uniform anticline on the extreme east. The overthrust fault no. 15, the direction of thrust of which was from the southwest, produced a northward as well as eastward displacement

of the strata from the southwest, thus bringing the axis of anticline 3 southwest of the overthrust [A, section 20] some 400 feet farther northeastward than its continuation north of this fault [A, section 15]. By this overthrust the western limb of syncline 3 [B, section 14, which corresponds to B, section 20] steepened from 30° to 60°, making this syncline nearly a closed fold.

Going southwestward from section 20, the axes of the folds continue to pitch downward, so that higher and higher strata come to form the surface. This is well shown by a comparison of sections 20 and 21 and by reference to the map. We pass from the New Scotland beds, which in section 20 form the present top of syncline 3 and anticline 2, to the Becraft and later on to the Port Ewen, only the steep eastern limb of syncline 3 remaining as a narrow band for each of the lower formations. The descent continues to fault 17, where an oblique shifting of all the strata occurs. Thus, as shown in section 22, the overturned western limb of anticline 3 (the only portion of that anticline remaining) is repeated, the repeated portion however being more strongly overturned. From this fault the axes of the folds rise southward, lower and lower members being progressively uncovered in the eroded anticlines. This is seen on comparing sections 22 and 23, the position of the latter with reference to the former being indicated by the dotted line in the lower portion of section 22. On comparing anticline 23 of sections 22 to 25, this same southwestward rise or northeastward pitch of the folds is shown. It is thus apparent that on opposite sides of fault 17 the folds pitch toward each other, and it is noteworthy that at this, the lowest point of the strata, the stream which has its valley wholly on the Oriskany outcrops, breaks across the strata to join Claverack creek. It is at this point that the axis of anticline 2 is so low that the hard limestones are carried below the present level of the stream on the Oriskany outcrop, thus making this the natural point of exit.

A comparison of sections shows, that the folds steepen toward the northeast and also become more closely crowded. Hence the lines marking the anticlinal and synclinal axes are closest

together in this portion of the map. The pitch of the folds is well shown by the outcrop of the Port Ewen and Oriskany of anticline 1 and syncline 1 and 2. The adjustment of the stream to the Oriskany outcrop, or more specially to the contact between the Oriskany and Esopus, is well shown [*compare* section 24]. Fault 18 cuts off these folds abruptly and, together with fault 19, which is its continuation, bounds this area. West of these faults, we have a strongly eastward pitching, simple syncline, with gentle northern and vertical southern limb. This is a section of syncline no. 1, which, from representing the upthrow side of the fault is alone found, all the more southern folds having been worn away [*see* section 26].

To the north of this syncline is a steeply eastward pitching anticline, which is apparently unrepresented in the other portions of the mountain. This fold is broken in the center, and a long narrow block, bounded by faults 20 and 21, has dropped down. Where these two faults converge, is a large, flat bottomed meadow, inclosed on all sides except the southwest, by steep banks which rise in places to a hight of a hundred feet or more. The meadow is drained through the open end by a westward flowing stream.

The sides of this depression are so steep and fresh and the bottom so flat, as to suggest some recent movement along the bounding fault planes. The inclosure on the three sides is so abrupt, as to make any other explanation difficult. Moreover, the bottom of the depression is underlain by the New Scotland beds, the same which form the sides of the hollow, and there is no assignable reason why one part should be so maturely eroded while the adjoining portion is still so fresh. It is not improbable that this impression represents a sink hole of unusual dimensions for this portion of the country. The approximate dimensions of the depression at the bottom are: length 650 feet; greatest width 300 feet [*see* section 26].

Beyond fault 21 to the northern extremity of the mountain, the structure is very simple and uniform, as shown by section 1.

A NEW EURYPTERID FAUNA FROM THE BASE OF THE SALINA OF WESTERN NEW YORK[1]

BY CLIFTON J. SARLE

With 21 plates

INTRODUCTION

In western New York the outcrops of the Salina strata occur in a belt of country averaging 10 miles in breadth, parallel to the southern shore of Lake Ontario, and its northern limit distant thence about 15 miles. On the Rochester meridian the formation is 600 or 700 feet thick, and, in the lower portion, comprises variously colored shales or marlites, interspersed with some thin layers of dolomite, while in the upper portion are salt and gypsum deposits with some beds of waterlime and limestone. The exposures of the formation in this part of the State are few, owing to the very destructible nature of the rock and to a heavy covering of drift. No sedimentary strata in the State have been considered more barren of fossils. Resting on the Lockport dolomite, which is everywhere replete with fossils, and underlying the Bertie waterlime, which at many localities carries a rich assemblage of eurypterid remains in the thin layers at the top, it has formed a conspicuous break in the paleontologic record.

It is therefore a matter of considerable interest to announce a rich eurypterid fauna, discovered by the writer in 1898, in the basal layers of the Salina formation, in Monroe county.

This fauna, though separated from that above by nearly the whole thickness of the Salina, is its counterpart in many respects but perhaps more primitive in its characteristics. The discovery thus affords additional ground in support of the comprehension within the Salina of all beds included between these faunas. Formerly this association was based entirely on stratigraphic succession and a supposed similarity of physical conditions, from which it was assumed that a similarity of life must be found.

It is safe to state that this is the earliest fauna yet known to which the name "eurypterid fauna" can be properly ap-

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[1] Since this paper was put in type it has been accepted by the faculty of the University of Rochester as a thesis for the degree of master of science.

plied. The remains from earlier formations are extremely rare and, almost without exception, very fragmentary. Eurypterus boylei Whiteaves (1)[1] was described from a single nearly complete body found in the Guelph dolomites underlying the Salina in Ontario; Eurypterus prominens Hall (2), from a cephalothorax referred on doubtful grounds to the Clinton of Cayuga county, N. Y.; fragments of Pterygotus were described by Barrande (3) from the Siluric of Bohemia; the genus Echinognathus Walcott (4) was described from a single limb found in the Utica shale (Lower Siluric) of New York; Eurypterina Walcott (5), from fragmentary remains found in the Belt terrane (Precambric) of Montana; and recently, the genus Strabops Beecher (6), from an essentially entire body found in the Cambric of Missouri.

Other forms of life occur with the eurypterids in this fauna, but they are comparatively inconspicuous and have no effect on the general facies.

The entire fauna comprises:

Graptolitida	1	Ostracoda	1
Annelida (denticles)	3	Phyllocarida	2
Brachiopoda	1	Synxiphosura	1
Pelecypoda	1	Eurypterida	6
Cephalopoda	2		——
		Total	18

Three species from the original collection made by the writer, have already been described by Dr John M. Clarke (7), viz, two phyllocarids representing the genera Ceratiocaris (C. praecedens) and Emmelezoe (E. decora), and a merostome belonging to the synxiphosuran genus Pseudoniscus (P. roosevelti). Five new species of eurypterids and a variety of one of these are here recognized, representing four genera, one of these being new to science. The specimens referred to four of the species are so fragmentary that at present they do not warrant complete determination, it being preferable to wait till more perfect examples have been obtained. These fragments, however, have been figured and will be referred to briefly.

[1] See references on p. 1109.

The collection was obtained from excavations made in deepening the Erie canal during the winter of 1897-98. The precise locality begins at a point a few rods east of the Brighton-Pittsford line in the latter township and extends southeast for a distance of about 300 yards. Though the exposure did not at any one point exceed 9 feet in hight, yet, owing to the dip of the strata toward the east, higher levels were brought down to view, so that the entire vertical section was about 16 feet.

The rock is a soft shaly marlite, in layers of different colors, often mottled, and interspersed with a few thin layers of very hard, fine grained dolomite.

The eurypterids are found in a rather fissile, very dark olive-green to black shale, which, like the adjacent argillaceous strata, rapidly disintegrates on exposure.

The beds of this section in descending order are:

		Feet	Inches
1	Red shale	6	
2	Light gray, compact, fine grained, dolomite, with imperfect conchoidal fracture, weathering light brown to cream color		10
3	Soft, gritty mud-rock, purple with bright red mottlings	1	3
4	Dolomite like no. 2		4
5	Purple shale with red mottlings	1	11
6	Green shale	1	2
7	Thin layer dolomite like no. 2		4
8	Black shale, very compact, the base splitting unevenly; grading to olive-green shale in the upper part		10
9	Dolomite like no. 2		10
10	Black shale, with leaf of dolomite ½ inch thick four inches from its base	1	2
11	Dolomite like no. 2		2
12	Soft, green, arenaceous mud-rock, occasionally becoming shaly; the lowest exposed rock of the cut	1	8

The eurypterid fauna occurs in the black shale, nos. 8 and 10 in the foregoing table.

The proximity of this cut to wells penetrating to the Lockport dolomite, and to exposures on the west branch of Allen creek within half a mile to the north, show that the section is located on the northern edge of the Salina formation, hence approximately at its base.

The accompanying table, representing the beds lying between the black shale and the Lockport dolomite, as well as those for some distance above, was made from an examination of well sections a little to the westward of the fossil locality, and from a series of outcrops along the creek. The level of the black shale is thus ascertained to be about 20 feet from the base.

Salina

		Feet	Inches
	From wells:		
1	Red shale or marlite	10	
2	Hard, fine grained, yellowish, dolomite, having an imperfect conchoidal fracture	2	
3	Red shale	1	
4	Break estimated at	3	
5	Dolomite like no. 2	3	
6	Green shale or marlite	4	
7	Red shale	1	8
8	Break estimated at about	2	
9	Green shale	2	5
10	Black shale, very fine textured, fissile, and with 1 inch dolomite parting (eurypterid horizon)	1	6
11	Green shale	1	
12	Dolomite like no. 2	2	
13	Green shale or marlite	6	
	From west branch of Allen creek:		
14	Light colored waterlime, some pyrites and sun cracks	5	
15	Pea-green shaly marlite	7	
		51	7

Niagaran

16 An impure yellowish porous limestone

17 Succeeded by an impure bituminous limestone made up of imbricating, shell-like domes etc.

The portion of this section which corresponds to that in the canal cut, is seen to show some differences. However, the rapid changes in character of the superposed beds may be taken as a good indication of the limited lateral extent of most of them.

The red shale appearing in the upper part of this section is the same as that exposed in the upper part of the canal cut. At Pittsford, 2 miles southeast of this cut, the canal is excavated through red shale mottled with green. At Cartersville, 2 miles farther southeast, this same rock occurs in the canal bed and 40 feet lower in the waste weir. At Fairport, 4 miles northeast of this, it is again exposed in the canal, and by well-borings is shown to have a considerable thickness at that place.

It thus appears that this red shale corresponds to the lowest division of the Salina recognized in western New York by Hall, and immediately overlies the stratum containing the fauna herein described.

A few important facts relative to the physical changes attending the introduction of the Salina fauna into the area are well illustrated by these sections. The exposures on the west branch of Allen creek, from which the lower part of this section was taken, show in the upper portion a progressive change of conditions: first, from those of the Niagara sea, in which stromatoporid reefs were widespread and an incipient Guelph fauna flourished, to those under which thin layered, impure, ripple-marked dolomite was deposited and fucoids appear to have been the only forms that abounded; then, to conditions for the formation of a tough, porous, very bituminous limestone, succeeded by a phase during which a stratum of thin-layered, bituminous accretionary limestone, forming flat, imbricating, shell-like domes,[1] was deposited; and, finally, to condi-

[1] This rock is the same as that south of Lockport, Niagara co. noted by Hall, *Geol. N. Y. 4th Dist.* p. 92, and also exposed in the southern part of the city of Niagara Falls. It is probably identical with that described by Vanuxem in the *Geol. N. Y. 3d Dist.* p. 91, as a limestone, small in quantity and in hemispheric concretions, whose parts are more or less concentric to each other like the coats of an onion, and regarded by him as an attenuation of the Lockport dolomite.

tions during which 2 feet of light yellowish impure limestone, showing on the weathered surface casts of a very finely branching organism, probably a plant, were formed. On this rests a greenish shaly marlite, the basal stratum of the Salina. The next layer consists of a bench of waterlime marked by shrinkage cracks, indicating a temporary exposure to the air during the time of formation.

It is thus seen that preparatory, as it were, to the coming of the Salina fauna, there was a marked change in physical conditions. The shallowing of the sea, with a probable increase of salinity and turbidity of the waters, probably had more than anything else to do with the displacing of the Niagara fauna. While these changes were going on, the first of the Salina fauna, a Pterinea, a little more rhomboid and convex than P. emacerata of the Rochester shale, appeared. Later, in the waterlime bench, besides the Pterinea, a Lingula, a Leperditia (L. scalaris), and also an Orthoceras, occur. With the exception of the last, which has not been noted elsewhere in this section, these fossils make their next appearance in the black shale, where they are accompanied by the eurypterids.

The eurypterids are by no means uniformly distributed throughout this shale. The species representing the new genus to be described, occurs most abundantly in the lower half, where it is so prolific that certain planes are literally packed with its remains, making this probably the richest eurypterid stratum known. The genus Eurypterus, represented by a single large species, occurs most frequently in the upper half of this black shale, just above the 2 inch limestone parting. The Pterygotus head [pl. 24, fig. 7] was also found in the upper portion.

The dolomite layers associated with this black shale are marked by an almost complete absence of eurypterids, the Leperditia and Pterinea, with the exception of an occasional specimen of a small pentalabiate Gomphoceras of characteristic Siluric type, being the only forms found in them. From the fact that the occupation of the area by the merostome fauna followed one of these dolomite-forming intervals, was twice

interrupted by the accumulation of marl, and finally was closed by another lime-forming interval, it is evident that the conditions at these times were not favorable to the eurypterids. These dolomitic limestones probably represent more open water, or the temporary removal of some barlike barrier, and, probably, a diminution in the salinity of the water. Though the fine character of the silt forming the black shale and the evidence of interrupted sedimentation noted above, indicate slow accumulation, the occupation by the eurypterids was apparently of comparatively short duration, merely an incursion, as it were, since the black shale all told does not exceed 2 feet in thickness.

The fact that the eurypterids are often dismembered and their parts distributed over considerable areas, and that a dozen or more are frequently found side by side, with a common flexure, suggests that they may have been drifted up by a current. On the other hand, the fine preservation of much of the material, extending even to the delicate appendages, shows that the currents were very weak, thus practically leaving the animals in the position of death or molting. Their grouping is very probably due also, in some degree, to their gregarious habits or to their abundance.

The tests of the eurypterids are black and carbonized. A line of dehiscence around the anterior edge of the cephalothorax indicates that in many cases these remains are moltings.

DISCUSSION OF SPECIES

Genus HUGHMILLERIA gen. nov.

By far the most abundant of the eurypterids occurring in this stratum of black shale near the base of the Salina, is a small form which, from its general appearance, in many ways suggests the genus Eurypterus, while a study of its structure shows it to be closely related to Pterygotus. It is evidently a new genus, which it is proposed to designate by the name Hughmilleria.

Generic diagnosis

General outline lanceolate. Cephalothorax semielliptic and flatly convex; compound eyes small, subelliptic and marginal; ocelli subcentral. Abdomen divided into distinct anterior and posterior regions. Preabdomen provided dorsally with six plain, transverse, bandlike tergites; ventrally with five sternites, the last three being essentially like the corresponding dorsal plates. First sternite cleft for the reception of a median appendage, which varies in form according to sex. Basing sexual distinctions on the determinations made by Holm in Eurypterus fischeri, this appendage in the female consists of a narrow, convex, scalelike, sagittate-based sheath, which appears to be formed by the fusion of two nearly equal portions, the anterior overlapping, and projecting posteriorly to cover partially a slightly shorter, simple, lance-linear appendage in a cleft of the following sternite. In the male the appendage is confined to the first sternite, the second being entire. It is proportionately shorter and broader, convex and lanceolate with the posterior free end slightly produced. Postabdomen composed of six ring segments. The first is readily distinguished from the segments of the preabdomen by postlateral prolongations. It appears to be formed by the fusion at their appressed ends, of a sternal and a tergal portion, the latter of which is the longer. The following segments are simple, bandlike rings. Telson long, lanceolate, with dorsal carination. Epistoma convex, peltiform, dividing in molting or under stress of compression, through the middle, joined at the sides to a narrow doublure. Preoral appendages attached at the pos-

terior end of the epistoma; short, stout, composed of three joints, the two distal a little shorter than the basal, and forming a pair of edentulous, bevel-edged pincers, which normally are folded back so that their tips converge close to the anterior end of the mouth. Endognathites increasing in length from the first backward, moderately robust, spiniform, composed of seven joints, of which the third to the sixth inclusive bear a pair of spines. Swimming arms narrow, lanceolate paddles, composed of eight joints and a rudimentary ninth inserted in a notch on the inner side of the eighth or palette. The proximal joint, or gnathobase, has the form of an upright retort. The seventh bears on the inner half of the distal end a subtriangular lobe demarked by a suture. Metastoma elongate, cordate.

Type, H. socialis Sarle.

Comparison with other genera

The characters suggesting Pterygotus are: the rounded triangular or semielliptic outline of the head as seen in Pt. banksii Salter (8) and Pt. raniceps Salter (8); the marginal, compound eyes; the slender body with slight constriction between the anterior and posterior abdominal portions; the cordate form of the metastoma; and the simplicity of the opercular plate and its appendage. The two forms of this appendage resemble those of Pterygotus as far as the material of the latter permits of comparison, one form being a slender, sagittate-based scale, the other a shorter, broader, convex body, as in Pt. bilobus Salter (11) and Pt. osborni Hall (10). In the new genus the first form projects posteriorly to protect a shorter lance-linear appendage lying in a cleft of the second sternite, while the second form is followed by an entire sternite without appendage. The sixth pair of cephalothoracic appendages resemble those of Pterygotus in being only slightly expanded distally and consisting of eight joints, with a rudimentary ninth inserted in the end of the palette. The gnathobases have the upright retort form.

This genus is distinguished most clearly from Pterygotus by the character of the preoral appendages. These are stout, three-

jointed, chelate organs, so short that when extended they barely equal one half the length of the cephalothoracic shield. The pincers are edentulous and bevel-edged and in their normal position lie folded over the basal joints so that their tips converge close to the anterior border of the mouth. Extended, these organs project beyond the border of the shield for perhaps half their length; when turned straight back, their tips lap over the end of the metastoma. In Pterygotus, on the contrary, these organs are very long, having, at least in Pt. bilobus Salter and Pt. macrophthalmus Hall, a length fully one third that of the entire animal; and consist of ponderous, dentate pincers supported on a slender, retrally tapering proximal joint of such a length as must necessarily have prevented the pincers being used at the mouth, unless these appendages were somewhat retractile, as suggested by Laurie (9).

The next important difference is in the character of the spiniform walking legs. As in Pterygotus, these consist of seven joints, but the several pairs present a greater contrast in their respective lengths, are proportionally more robust, and each joint from the third to the sixth inclusive, carries a pair of ventrally and distally articulated, slender, curved spines. It is doubtful if any species of Pterygotus has spines on these appendages; certainly, in several species in which these limbs have been found apparently well preserved, they are lacking.

Woodward (8) represents Pt. taurinus Salter as having a spiniferous endognathite. Laurie, in his *Anatomy and Relations of the Eurypteridae* (9), in one place states that there is no elaborate development of spines on the endognathites of Pterygotus. Earlier in the same paper, however, he makes the statement that they are destitute of anything in the way of spines and, in a comparison of the appendages of Slimonia with those of this genus, offers this explanation: "These [dentate, preoral] appendages, unlike those of Slimonia, were probably prehensile rather than masticatory, and this function may account for the absence of spines on the other limbs (endognathites), which are purely ambulatory." The converse of this may be stated of Slimonia, and also of Hughmilleria, since

the pincers are edentate and the walking limbs carry light, claw-like spines.

The epistoma, instead of parting on either side from the doublure by stress of compression or in molting, as an epistoma of Pterygotus figured by Laurie (9) did, is seen to have divided through the center, an occurrence observed in a large number of specimens. Schmidt (12) figures an epistoma of Pt. osiliensis Schmidt, which, while showing a tendency to divide along sutures at the sides, has also a deep open cleft in the posterior edge. It is evident that there is considerable variation in this plate in different species.

The last of the differences lies in the telson, which is slenderly lanceolate and much longer than that of any known species of Pterygotus.

Regarding its resemblance to Eurypterus, it might be said that, but for the marginal position of the eyes and relatively large chelae, this form would easily be mistaken for a species of that genus. The semielliptic form of the head and the slight expansion of the swimming arms, recall E. lanceolatus Salter (8), and the slender telson gives the posterior part of the body of a general Eurypteruslike appearance, hightened by the spiniferous character of the walking legs and the short, edentulous, masticatory preoral appendages.

However, the walking legs are less robust. They consist uniformly of seven joints and are equally spiniferous, while in Eurypterus, with the exception of the first pair, there are more than seven, and the fourth pair carries merely the three end spines. In the preoral appendages, the basal joints, instead of being flat expansions on which the pincers are articulated (15), are segments a little longer than the pincers, which, in their normal position, instead of hanging down over the mouth, do not quite reach its anterior end. These pincers have been seen in Eurypterus only in the Russian species E. fischeri. The limbs of the sixth pair are less expanded at the ends than is usual in Eurypterus, and have narrow, upright, instead of heavy, subquadrate gnathobases. The operculum is simpler, lacking the faint transverse suture and two subtriangular

areas which in the female Eurypterus lie in front, one on either side of the median suture. The parts of the genital appendages correspond in a general way to those of Eurypterus, though there is considerable difference in their form. In the female the appendage consists of two parts, one carried by the operculum, the other by the following sternite. The part carried by the operculum is slender with a sagittate base, and is divided transversely into two portions, but lacks the pair of short, flat, diverging, terminal crura. That carried by the second sternite is simple, broader at the base and attenuated at the distal end, instead of having articulated to it, two diverging, ensiform strips (14). In the male, as in Eurypterus, the appendage is confined to the operculum, and is shorter and broader than that of the female; but is proportionately larger than in that genus.

The genus Slimonia is suggested in three ways: by the marginal position of the compound eyes, by the shortness and edentulous character of the masticatory preoral appendages, which are, however, less robust in that genus, and by the length of the telson and the slight indication of inflation in the anterior portion. In other respects there appears to be considerable difference between these genera.

From a consideration of the foregoing facts, it appears that Hughmilleria is most closely related to Pterygotus. With Pterygotus and Slimonia, it makes three genera of eurypterids having the compound eyes marginal. In development of preoral appendages, it comes between Pterygotus and the other genera in which these appendages are known, including Eurypterus, Dolichopterus, Stylonurus, Eusarcus and Slimonia.

Hughmilleria socialis sp. nov.

Plates 6–9; 10, fig. 1–6, 8–9; 11–14; 15, fig. 4–6; 24, fig. 1; 25, fig. 1 ,3, 4; 26, fig. 3, 5

This type is comparatively small, the length of the average individual not exceeding 15 cm. Viewed from either the dorsal or the ventral side, the outline is slenderly lanceolate. In the natural, undistorted condition, the anterior part of the body is flattened, the dorsal and ventral surfaces being slightly convex, while the caudal portion is nearly cylindric.

Cephalothorax. The cephalothorax is semielliptic or subtriangular in outline, the length equaling the breadth at the base, and comprising about one fifth the length of the entire body. Along the gently curving sides and acutely rounded front is a narrow flattened border, striated on the under surface, and not exceeding a fraction of a millimeter in breadth. The dorsal surface is slightly rounded or arched from the side to the center, so that in an undistorted shield 22 mm long, the elevation is about 2 mm. The posterior edge, except for a slight forward curve at the genal angles, is straight. The compound eyes barely break the outline of the shield; they are small, elongate, widest anterior to the middle, the outer side arcuate, the inner formed by three nearly straight edges—a short basal and a little longer anterior, forming slightly rounded obtuse angles with a long inner side. The anterior end of the eye is acute. The length of these organs on the cephalothorax, the dimensions of which were given above, is 5 mm. However, the usual proportion between the length of the shield and eye is as 1:4.5. A line drawn connecting the posterior ends of the eyes passes through the center of the shield. The ocelli are situated on a small tumescence cut by this line; they form two minute, ringlike prominences separated by about the length of their diameter.

Abdomen. The abdomen, at the widest point, or between the third and fourth dorsal segments, is a little wider than the base of the cephalothorax. Thus, in one animal measured, these dimensions were respectively 24 mm and 17.5 mm, in a second 23 mm and 17 mm, and in a third 33 mm and 26 mm, probably varying somewhat according to the amount of compression and also somewhat with the animal. From this point the abdomen tapers very gradually to the telson; it is divided into anterior and posterior parts, easily distinguished by their structure. The preabdomen consists of six dorsal and five ventral, transverse plates; the postabdomen of six annulate segments and one spiniform.

Preabdomen. The first tergal plate of the preabdomen is very narrow and is overlapped by the posterior margin of the shield. Its posterior edge is slightly convex, and its ends are rounded.

The second segment is twice as long as the first, its posterior edge is slightly concave along the middle portion, and the posterior angles are rounded, while the anterior are produced, to make up, as it were, for the rounding away of the preceding tergite. The succeeding tergites are very nearly equal in length, the fifth being perhaps a little the longest, and are about one third longer than the second. The posterior margins are concave as in the preceding, but straighter near the sides, forming almost right angles.

The first ventral plate, or sternite (the operculum), is one third as long as broad, and is divided along the axial line into two equal parts. These are rounded off at the lateral angles, particularly the anterior, and excavated along the median line for the reception of the opercular appendage; the posterior edges are slightly projected on either side of this, while the anterior inner angles are projected forward, forming a compound median lobe. The second sternite, in the female, is nearly as long as the operculum, and is deeply cleft for the reception of an appendage nearly equal to it in length. The sides are cut obliquely forward, making the posterior angles rather acute; the anterior angle forms small lobes, and the middle of the anterior edge is slightly produced. In the male the last four sternites, and in the female the last three, do not differ materially from the last four and three abdominal tergites. The relative position of the several plates of the sternal series to those of the tergal, is as follows: the opercular plate begins a little farther forward than the first tergite, but, owing to its greater breadth, lies beneath the line of overlap of the first and second tergites, while the second sternite lies beneath the overlap of the second and third tergites, and so on, the last sternite underlying the overlap of the fifth and sixth tergites, thus not extending as far back as the posterior edge of the sixth tergite.

Postabdomen. The first postabdominal segment consists of a tergal and a sternal portion united by their appressed pleural ends. The postlateral angles are prolonged into short, bladelike lobes which extend alongside the following segment for fully half its length. The tergal portion is the longer,

and its posterior edge forms a broad lobe; the sternal portion is short, and its posterior edge is straight, while its anterior edge extends forward to meet the last sternite of the preabdomen. The following five segments are plain, bandlike rings, decreasing in breadth backward. In the first the breadth is considerably greater than the length; in the last, or penultimate body segment the length and breadth, in compressed specimens, are equal. The anterior end of each of these segments is marked by a groove for the attachment of the interarticular membrane.

The telson is very slenderly lanceolate, widest near the anterior end and attenuated at the tip. In length it is equal to the four preceding segments. The dorsal surface is convex, rising from sharp, lateral edges to a median longitudinal carina, which begins in the anterior part as a broad, angular prominence; the ventral surface is nearly flat or faintly convex; a cross section is thus subtriangular. Compression usually flattens the sides and thus hightens the angular appearance. The uncompressed specimen [pl. 15, fig. 6] has a length of 31 mm and a greatest breadth of 7 mm.

On the ventral surface of the cephalothorax, in front, is a convex lobe or platform, the *epistoma,* from which extends a flat, tapering doublure ending in a small expansion at the genal angles [pl. 11, fig. 6 and pl. 12, fig. 2]. In molting and also from compression, the epistoma divided through the middle rather than along the sides [pl. 12, fig. 2].

Appendages. The *preoral* appendages are short, stout, three jointed, chelate organs attached at the posterior border of the epistoma [pl. 11, fig. 7]. The two distal joints of each form a pair of broad based, edentulous, bevel-edge pincers, in the ordinary state of compression having a breadth equal to one half the length. The blades are about equal in length to the basal portion and meet at the very acute, slightly curved tips and again, usually, only near the base. There is considerable variation in the relative form of the pincers, as shown on plate 11. The broad basal joints are about one fourth longer than the pincers, widest near the base and longest on the inner side, and in

the natural position extend beyond the anterior margin of the shield for about one third their length. The pincers articulate with this joint in such a way that, when folded backward, they cross it obliquely, and their tips converge a little in front of the mouth; when extended forward, they diverge somewhat. The preoral appendages could also be turned back to their full length over the mouth, the pincer tips then overlapping the metastoma [pl. 11, fig. 6]. In an individual having a cephalothorax 22 mm long, the preoral appendages are 10 mm long. (Plate 9, figure 1, shows these organs from the dorsal view, the cephalothorax having been removed.)

The four pairs of *endognathites,* or crawling legs, do not differ materially from one another except in length. The anterior limbs are somewhat shorter than the extended preoral appendages, and their tips extend but very little beyond the margin of the shield. Each succeeding pair is about one half longer than the preceding, so that the last limbs are probably four times as long as the first. All have seven joints, of which the terminal is spiniform. The third to the sixth joints inclusive carry ventrally and at the distal ends a pair of striated, slightly curved, slender spines. The inner spine of each pair is the longer, and the length increases for each successive set, from the third to the fifth joints; the spines on the sixth are short. The coxal joints are elongate, slightly curved, widest at the base and equal in length to the succeeding two joints. They increase in length with each successive pair, and bear on the inner end a series of 15 or more, sharp, curved teeth, which decrease in size from the front. On each of the fourth coxal joints is a large perforation of the upper side near the fixed end [pl. 26, fig. 5]. No epicoxite has yet been observed. The second joint of the endognathite is divided by constrictions into three transverse sections. It is articulated at the fixed end of the coxal joint and is fully two thirds as wide.

The limbs of the sixth pair are narrow and paddlelike, and consist of eight joints and a rudimentary ninth or claw, the seventh and eighth forming a slightly expanded blade. The seventh carries a large, subtriangular, lobelike plate, nearly one half as

long as the joint proper, marked off from the inner, distal end by a suture. The eighth, or palette, is elongate oval with the margin finely incised, and carries the minute claw inserted in a notch on the inner side near the tip. On the dorsal surface of the seventh and eighth joints, at the proximal end and outer edge of each, is a group of minute, craterlike tumescences, which were probably receptacles for the bases of hairlike bristles [pl. 14, fig. 8]. In a swimming arm 29.5 mm long, exclusive of the gnathobase, the narrowest joint or the fourth, measures 5 mm across; from this point the arm gradually enlarges to 6.8 mm on the seventh and eighth joints. When the swimming arms are turned back, they reach the line of the fourth or fifth dorsal segment. The gnathobases have the form of an upright retort. The inner extremity of each is provided with from 18 to 20 sharp, slightly curved teeth, which become finer posteriorly. A gnathobase, accompanying a cephalothoracic shield 22 mm long, is 16 mm long; the width of the narrow necklike portion 6 mm; the width at the base 13 mm.

The metastoma is elongate cordate, the greatest breadth coming anterior to the middle. The smaller, or posterior end, is truncated and has rounded corners. The anterior notch is rather deep and broad. A comparison of the length to the greatest breadth of several metastomas gives the proportion of 2 : 1. In an individual having a cephalothorax 23 mm long the metastoma is 16 mm long.

The *genital appendage* differs noticeably in the two sexes. In the female it consists of two parts, one carried by the operculum, the other by the second sternite [pl. 13, fig. 1, 2]. The opercular appendage is a slender, sagittate-based, convex, scalelike sheath projecting for about one fifth its length beyond the posterior edge of the operculum and appearing to be formed by the fusion of two parts. The anterior of these includes the sagittate base and a narrower, more convex portion with a flattened border on either side [pl. 13, fig. 4]. Its distal end is reentrant [pl. 24, fig. 1] and fused to the posterior part. This part is a little narrower, slightly tapering and beveled in from either side for one fourth the breadth, to the sides of a slightly raised platform which is flat topped for the greater part of its

length, but becomes concave posteriorly, forming a shallow groove at the abrupt end. The terminal angles are noticeably truncated. The appendage carried by the second sternite is partially covered by that of the operculum [pl. 14, fig. 2]. It is very slender, its greatest breadth not exceeding one sixth the length [pl. 26, fig. 3; 13, fig. 4]. The anterior half is sublanceolate with a triangular base; the posterior is attenuate and terminates just within the end of the cleft. In the male the appendage is simpler and confined to the operculum, the following sternite being entire [pl. 13, fig. 3]. It is wider and somewhat shorter than that of the female, the average length being only about two and one half times the breadth. It is convex, broadly lanceolate and slightly produced at the posterior free end which just clears the edge of the operculum. A specimen in which a portion of this organ is scaled away [pl. 14, fig. 1] gives a cast of the interior showing small elevated lines radiating from near the center backward, and may possibly represent part of the vascular, or duct system of this organ. The two sexes are about equally represented in numbers.

The whole surface of the body is covered with imbricating, crescentlike or angular scales, sometimes carrying smaller ones of the same pattern. These scales are so minute on certain areas as to appear almost obsolete. They are most conspicuous on the ventral side of the preabdomen and appendages. On the cephalothorax and abdomen the scales point backward, on the paired appendages toward the distal end, and on the epistoma, forward.

Hughmilleria socialis var. robusta *var. nov.*

Plate 21, fig. 1, 2

What appears to have been a varietal form of Hughmilleria socialis is represented by a nearly entire abdomen, two first ring segments and an imperfect metastoma.

The features which distinguish this form are: its larger size; proportionately much greater breadth; the greater convexity of the dorsal posterior edge of the first ring segment and, in some cases, the division of this edge into two, broad, smooth lobes; the more noticeable contraction of the abdomen at the

second ring segment; and the more rotund form of the metastoma.

The abdomen found lies in the shale dorsal side up, showing the anterior nine segments well preserved. The second and third ring segments are partially disconnected. The breadth of the preabdomen at the widest point, or between the third and fourth segments, is 51 mm, its length 56 mm, the breadth of the first ring segment is 42 mm, of the second 30 mm. The dorsal posterior edge of the first ring segments is entire and very noticeably convex. In each of the isolated ring segments a broad, deep notch produces a bilobation of this edge. A line of pittings close to this edge shows this feature to be natural. The proportions of the more perfect of these segments are: breadth 43 mm, length of the dorsal side 22 mm, length of the ventral 11 mm, length of the postlateral lobes 8 mm. The metastoma associated with one of these segments is apparently of a smaller individual and lacks the anterior notched end. At the widest part it measures 14 mm and, from there to the posterior end, 14 mm.

It was at first thought that the distinctive features of these specimens might be merely old age characters of H. socialis, but larger individuals of that species seem to show the same relative proportions as the smaller. However, it is considered that the differences shown by the incomplete material of the collection are not, of themselves, sufficient to warrant the founding of a distinct species.

Genus EURYPTERUS DeKay. 1825

Eurypterus pittsfordensis sp. nov.

Plate 10, fig. 7; 15, fig. 1–3; 16–23; 24, fig. 2–5; 25, fig. 2, 5, 6

This species is comparatively rare and is not represented in the collection by any entire individuals. There is however sufficient material to enable its main features to be correctly determined.

The entire animal is large and robust, and broadest at about the third segment. The cephalothorax is two thirds as long as broad, eyes of medium size, appendages heavy. The preabdominal and postabdominal portions are not strongly differ-

entiated; the telson long, probably equal in length to the five preceding segments.

The cephalothorax is broad, rounded in front, the sides curving out near the genal angles, and the base straight, or very gently curving over the middle portion, and extending a little forward near the sides. The margin is beveled in for a distance, in the average sized individual, not exceeding 2 mm in the widest part or in front, narrowing and fading out at the genal angles. The extreme edge is slightly upturned. The compound eyes are separated by one half the breadth of the shield, with their bases in line with its center. They are prominent, reniform, broader at the anterior ends, and one fifth as long as the shield. The ocelli are situated on a faint tumescence between the centers of the compound eyes. They are rather large and separated by about their own diameter. Near the basal edge of the shield is a pair of sharp, raised, triangular scales, one on either side of the axial line. In some cases there is a row of shallow, flat bottomed pits on the beveled margin.

The abdomen increases slightly in breadth from the base of the cephalothorax to the third segment, then tapers to the telson, there being no apparent constriction between the preabdomen and postabdomen. The tergites are comparatively short, the length averaging a little less than one fifth the breadth. They are broadly concave along the middle of their posterior edges, and each carries, bordering this curve, four raised, triangular scales like the two on the posterior border of the cephalothorax and the middle two in line with them. The five sternites are medially cleft and marked by transverse sutures, which give to each the appearance of having been formed by the fusion of two plates. With the exception of the first or operculum, they have the anterolateral angles projected forward into small lobes. In the operculum these angles are noticeably rounded away, and the anterior edge is projected into a broad median lobe. In the female the second sternite has a similar lobe. The annulate segments, or sclerites, comprising the postabdomen increase in length and decrease in breadth from the first, which is very broad and short, to the

last in which the length exceeds the width of the anterior or wider end. They are depressed and have faintly defined pleural areas or flattenings at the sides. Each is prolonged on either side, at the posterior angle, into a short, striated spur, which grows longer with each succeeding segment, those on the last forming conspicuous pointed lobes. The first two segments each carry on the dorsal side four triangular scales like those of the preabdomen, the third, fourth and probably the fifth, each two, the last none. This segment has a shallow notch in the middle of the dorsal, posterior edge, marked on either side by a small denticle, succeeded toward the sides by very minute ones. The series of striations of the lobes continue up the sides of the segment to its articulation with the preceding. On the ventral portion of each ring segment is a shallow posterior emargination fringed with lobelike teeth. Extending forward from near either end is a curved rent, a pair sometimes almost inclosing an irregular, oval area.

The telson is very long, nearly equaling in length the rest of the postabdomen. For a short distance from the anterior end it contracts rapidly, then continues slender to the abruptly rounded point. The edges are sharp and, from near the anterior end, are marked by short, oblique incisions. The dorsal surface is smoothly convex, the ventral has a flat topped carina which begins near the proximal end and extends to the tip. On the carina is a double row of pits like those bordering the cephalothorax.

The doublure, at its dehiscence in the axial line, equals in width about one fourth the length of the cephalothoracic shield. From this point it narrows toward the genal angles.

The preoral appendages have not been observed. The endognathites are robust and vary greatly in length, the first pair being barely long enough to reach the shield border, while the members of the third clear it by fully three fourths their length. The fourth pair is known only by a coxal joint and a basal portion consisting of three joints. The first legs consist of seven joints; the second and third each, of eight. In the first three, each joint from the third to the penultimate is provided with

two long, curved, striated spines. The terminal joints are comparatively long and clawlike. The coxal joints are large. The first three are short and broad, the length being a little less than two thirds the breadth. They have narrow, curved, postlateral prolongations equal in length to the second joint. The lower, inner angles are rounded and crenulated. The dentate faces at the inner, upper angles are on slight prolongations, which grow longer with each succeeding coxa. All three begin with two or three isolated, anteriorly directed, lobelike teeth, followed by slender conic ones, which become finer toward the posterior end. The fourth coxal joint is comparatively long. The inner lower angle is gently rounded away, and the neck supporting the narrow dentate face, long. The teeth appear to be comparatively few and coarse. The epicoxite of the third left coxa is shown on plate 16, figure 1.

The swimming arms are stout and moderately long, extending back nearly to the fifth tergite, and consist of nine joints. The gnathobases are subquadrate and large, and are provided with seven or eight short, bevel-edged denticles, the two anterior being large and prominent. The length of the gnathobase [*see* pl. 15, fig. 1] was 33 mm, its breadth 30 mm, the length of the dentate face 8 mm. The middle joints have the anterior and posterior angles sharp, in the fifth the anterior forming a blunt, striated spine, much like those at the sides of the postabdomen. The seventh and eighth joints are broadly expanded, and their margins, particularly in the latter, are marked by sparse, shallow serrations. Inserted on the inner side and near the end of the eighth joint, is a small, oval, rudimentary ninth joint.

The metastoma is elongate ovate, widest in the middle, with ends truncated. The anterior or narrower end is notched and minutely dentate.

The genital appendages of this species, so far as they are preserved in the material of the collection, are, with the exception of the part carried by the second sternite in the female, essentially like those of E. fischeri Eichw., as described by Holm (13). That of the female is the more complex and is carried partly by

the operculum and partly by the second sternite. The part carried by the operculum follows two subtriangular areas formed by a pair of sutures extending posteriorly from either side of the median lobe to meet the cleft, and extends considerably beyond the posterior edge of the plate. It consists of a short sagittate base and a slender portion divided transversely into two imbricating sections, each terminating in a short bifid expansion [pl. 24, fig. 5]. In E. fischeri there is a third part consisting of two, short, flat, diverging crura. As this appears to be a general feature in Eurypterus, it is probable that it exists in this species also. The part of the appendage carried by the second sternite is covered by that of the operculum. It lies in the median cleft which extends through the posterior two thirds of the sternite, the anterior third of the two halves of this plate being fused [pl. 25, fig. 5]. It is slender, being about one fourth as wide as long and does not quite reach the posterior edge of the sternite. The anterior end is slightly constricted where it fuses with the sternite, and the distal is tapering. The male appendage is confined to the operculum. In the material of the collection is a single specimen showing [pl. 25, fig. 2] the exterior, the others showing the internal form only. It was evidently small, about one fifth the length of the operculum by which it is surrounded.

The body is covered with comparatively coarse, imbricating, crescentic scales, most distinct on the sternites and swimming arms. When the integument of the metastoma and paired appendages are scaled away, there remains a punctate surface. The specimens found show that the size of these animals averages from 20 cm to 30 cm. A fragment of the third joint of a swimming arm was found, however, which appears to have been part of an individual over 60 cm in length.

Genus PTERYGOTUS Agassiz. 1839

Pterygotus monroensis *sp. nov.*

Plate 24, fig. 7, 9

This species is founded on a single specimen, a cephalothoracic shield. The outline of this shield is semielliptic with

the posterior edge noticeably incurved. The surface is moderately convex, and along the sides and front is a threadlike border. The length of the shield, without the genal angles, is 30 mm, with them 37 mm; the breadth at the base 38 mm. The compound eyes are prominent and project beyond the outline of the shield. They are subelliptic, with a distinct angulation on the inner side of each, produced by an indentation of the inner anterior part. They are 14.5 mm long and 6 mm wide. The facets can be made out with a good magnifying glass. The eyes are located a distance equal to their own length from the front of the shield and 27 mm from each other. A line connecting their bases cuts the axial line a little back of the center of the shield. The ocelli are on a small tumescence just back of this. The ornamentation is almost obliterated, but can be made out at one point, where it consists of minute, short, flat, lobelike scales.

Out of the eight species of Pterygotus that have been described from American strata, and all from the Bertie waterlime, the cephalothorax of but one has been identified, that of P. macrophthalmus Hall (10). Pohlman (14) described and figured one, but did not refer it to any species. It seems probable that it is of an older individual of P. macrophthalmus.

The cephalothorax of this new species differs from that of P. macrophthalmus in that its length is nearly equal to its breadth; the compound eyes are over one third the length of the shield, elongated, angulated on the inner side, situated farther back, and separated by nearly twice their length. In P. macrophthalmus (15) the length of the shield is three fourths the breadth; the eyes are about one third the length of the shield, anterior, globular and separated by a distance about equal to their length.

In form the eyes of this species suggest those of the erettopterid species (subgenus Erettopterus Huxley), P. bilobus Salt. and P. banksii Salt. and also those of H. socialis.

Fragments of Pterygotus

Plate 24, fig. 6, 8

In addition to the cephalothorax described above, other parts were found, mainly mere fragments, having the coarse, scaly ornamentation of Pterygotus, but even the more perfect can not be referred to definite species, because of their isolated condition. Among these is an ovate metastoma [pl. 24, fig. 8] 27 mm long and 16 mm wide, broadest just anterior to the middle, with the anterior corners slightly truncated, the lobes small and the terminal notch very narrow and shallow. It is marked by coarse, rounded, lobelike scales and is very much more robust than would be expected in Pterygotus monroensis. Judging by the ornamentation, it should be associated with the coarse scaled fragments most frequently found.

The broken, free ramus of a chela of a Pterygotus is represented on plate 24, figure 6. The shaft is nearly parallel sided, 3 mm broad and 12.5 mm long and curves at the end into a stout, striated, nearly perpendicular mucro 3.5 mm long. Back of this mucro is a series of 10 erect, subtriangular, striated denticles, very slightly separated at their bases. They are of three sizes, the largest or primaries being about one half the length of the mucro, the secondaries one half that of the primaries and the tertiaries about one half that of the secondaries. The first primary is separated from the mucro by a secondary and from the second primary by two secondaries and two tertiaries alternating; following the second primary are two secondaries separated by a tertiary.

The free ramus of Pt. buffaloensis Pohlman (14) differs from this in having the shaft convex on the inner side; the teeth perpendicular, numerous, acute, varied in length, one or two longer ones about midway in the series; and the mucro set at an acute angle.

In P. cobbi Hall (10), the only other species of the Waterlime in which this ramus is known, it is many times larger than this fragment; shaft tapering; mucro less erect and blunt tipped; teeth six, comparatively short, strong and unequal.

Another fragment [pl. 24, fig. 1] represents the basal part of the long, tapering, proximal joint of a chela of a Pterygotus.

These fragments show the genus Pterygotus to be fairly well represented in the black shale by species, though not by numbers.

Genus (?)

Plate 26, fig. 1, 2, 4

An eurypterid differing very materially from anything described from the Bertie waterlime, is represented in the collection by a group of four incomplete arms and a body segment, and by another of two incomplete arms.

In the first group [pl. 26, fig. 2] the longest of the arms has the coxal and succeeding five joints preserved. These are long, measuring altogether 110 mm in length. The three distal bear a series of long, curved spines. The form of the coxal joint is subtrapezoidal, the anterior side being considerably the longer. The breadth and the mean length are each about 18 mm. The dentate border is slightly produced and in length is equal to about one half the breadth of the joint. The dentation begins at the front end with an isolated, blunt tooth pointing forward, followed by sharp, curved teeth of small size which grade posteriorly into fine, hairlike bristles. The anterior side of each joint from the second to the sixth inclusive, is arcuate. The posterior sides of the second and third joints are straight, of the fourth, fifth and sixth, concave. The distal end of each is at right angles to the long axis. The second joint is narrower (14.5 mm) than long (23 mm); the third just twice as long (28 mm) as wide (14 mm); the fourth a little longer than the preceding (30 mm) and less than half as wide (7 mm). Along the concave, posterior side of the fourth are articulated five, long, curved, striated spines, nearly perpendicular to the joint. At the distal end of the series there is an indication of another. The most complete of these spines is 16 mm in length. The fifth joint is 16 mm long and 6 mm wide. Near the anterior end of the posterior edge it carries the stump of a large spine followed by the sockets of four more. The sixth joint bears the basal portion of three spines, but is so crushed and foreshortened that neither the original number of spines nor the length of the joint can be determined. Judging by the taper of this arm, there may have been two more joints.

The remnant of another appendage appears to be part of the proximal four joints, and measures 32 mm in length. From its robustness, it seems to have belonged just in front of the last mentioned. The peculiarities of these joints are their shortness and their thickening at the articulations. The joint, which on the tablet lies nearest to the large arm, is a little inflated and, though very imperfect, has the appearance of being the coxal joint.

The two other appendages of this group are robust and short. One is tolerably complete, apparently lacking only the dentate border of the coxal joint. It is 38 mm long and consists of seven joints. The coxal is large and globose. Each joint from the second to the fifth carries on the posterior edge a pair of short, stout, distally directed, lanceolate spines, averaging 2.5 mm long and nearly half as wide. Joint two is broad and very stout. Joints three, four and five are subquadrate and successively smaller. Joint six is nearly one and one half times as long as broad and at the end bears two distally directed spines, one anterior, the other posterior. The seventh is long and clawlike, slightly inflated at the base. The other appendage is so crushed and folded that little can be determined by it. However, from the larger size of the coxal joint, it is probable that its position on the body was behind the more complete. The spines preserved on it, like those of the smaller appendage, are short and lanceolate.

The body plate in this group is very narrow (76 mm) as compared to its length (23 mm). Its division into right and left halves by a suture, the arching of each half and the produced anterolateral angles indicate it to have been a paired sternite.

In the second group one of the imperfect arms consists of the four distal joints, the other of two imperfect proximal joints. The joints of the former are short and expanded at the articulations. The first and second are each provided on the posterior side with a pair of distally directed spines. These are long, curved and sharp like those of the large arm of the other group. The second has also, on the opposite side of the distal angle, a single, large one extending parallel with the axis of the arm. The penultimate is long and shows no sign of having been

spiniferous. The terminal is about equal in length to the spines and, like the terminal appendage in the other group, is clawlike. This arm, judging from the shortness of the joints and the broadening at the articulations, probably corresponds to the second described from the other group. The joints of the other arm appear to correspond to part of joints two and three of the first of that group.

Associated with this last, and lying partially beneath its larger end, is a fragment of test which is ornamented by sharp, triangular scales differing from anything found on the other eurypterids herein described. However, it is not certain that this had any connection with this arm. Aside from this possibility, neither the appendages nor the sternite show any signs of ornamentation.

The most noticeable features revealed by these specimens are: the robustness and the great difference in size of the several pairs of endognathites; on the anterior three of these, the arrangement in pairs of the posterior spines, which, on the first two, are noticeable for their shortness and lanceolate form, and on the third for their length and curvature; the high degree of specialization of the fourth pair of endognathites, shown by the great length of the joints and the number and large size of the spines; the narrowness and proportionately great length of the compound sternite; and the probability of there being several compound sternites. It is evident that the animal had a long, slender body with long, very strong limbs.

From a comparison of these parts with those of the various genera of eurypterids, it appears that they do not agree very closely with any. To show this, it is necessary only to point out certain of the more evident differences. In Eurypterus proper the fourth endognathite, to which I consider the longer of these arms to correspond, consists of nine joints, probably a greater number than is possessed by the other; besides, it bears no spines except the two formed by the prolongation of the eighth or penultimate joint. On the three anterior pairs of endognathites the spines are more uniform in shape and

size. The body is proportionately broader and shorter than that indicated by the sternite described above. In eurypterids of the type of Eusarcus scorpionis Grote and Pitt (15), Carcinosoma newlini Claypole (16), Echinogathus clevelandi Walcott (4), Eurypterus punctatus Salter. E. scorpiodes Woodward (8), E. scoticus Laurie (17), etc., so far as material shows, the preabdomen is obese, the second pair of endognathites is the longest, and all four pairs with their spines are curved forward. In Stylonurus and the related genus, Drepanopterus (17), the fourth endognathites are without any elaborate development of spines, and in the former are greatly elongated. In Slimonia the first pair of endognathites is tactile, the succeeding three pairs are short, vary little in size and are all provided with small spines at the distal ends of the joints. In the Pterygotus the four pairs of endognathites are filiform, of nearly equal size and probably in all cases, spineless.

It seems quite probable that, with more perfect material, this form will be found to represent a new genus.

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Plate 1

Ledge of Cobleskill limestone at Schoharie N. Y. Hammer marks division from the Salina shales.

PRELIMINARY OBSERVATIONS ON THE COBLESKILL ("CORALLINE") LIMESTONE OF NEW YORK

BY C. A. HARTNAGEL

More than 50 years ago Professor Hall[1] described a fauna obtained from a thin mass of limestone outcropping near the base of the Helderberg at Schoharie N. Y., which, on account of its great abundance in corals, had become known as the *Coralline limestone.* This is the lowest of the many limestone formations in the vicinity of Schoharie. In its western extension it was traced by its characteristic fossils as far as Herkimer county.

From the paleontologic and stratigraphic evidence furnished by the study of this limestone and also from a similarity in lithologic features, Hall concluded that the "Coralline" represented the attenuated eastern extension of the entire Niagara group as it then was known in western New York. The evidence for correlation furnished by the 25 species of fossils specifically identified from the "Coralline" was somewhat meager. With the exception of the corals, Spirifer crispus Hall was the only species described as identical with the Niagara fauna, and even that has been shown to be a variety.[2] Besides one or two species of Stromatopora found in this rock and having but little value in correlation, the abundant Favosites was identified as F. niagarensis (?), while Halysites catenulatus[3] Linn., which at this time was not known above the Niagara, was considered the most important of the fossil forms in the correlation of the two rock masses. The many characteristic species of the Niagara however were absent, while the "Coralline" was characterized by a peculiar gastropod and cephalopod fauna, a feature noticeably absent in the Niagara of western New York. These discrepancies between the two faunas were observed by

[1] Palaeontology of New York. 1852. 2:321–38, pl. 72–78.

[2] Grabau. Geol. Soc. Am. Bul. 11:352.

[3] This fossil was known above the Niagara only in the sense that Hall regarded the overlying waterlime as Salina. Vanuxem had recorded this species from the base of the waterlime group and had given the position of the waterlime above the Onondaga salt group. This coral was identified by Vanuxem as Catenipora labyrinthica. Geol N.Y. 3d Dist. 4th An. Rep't. 1840. p. 376.

Hall, and he attributed these differences to the unlike conditions under which sedimentation took place and to the unequal depth of the sea. Happily, however, the "Coralline" was described as a distinct formation.

The position, in the rock series, given to the "Coralline" at Schoharie appears to have been based chiefly on its relations to the overlying and underlying beds which Hall regarded as the Salina and the Clinton respectively. With these determinations it was impossible to conclude that the "Coralline" was other than the Niagara.

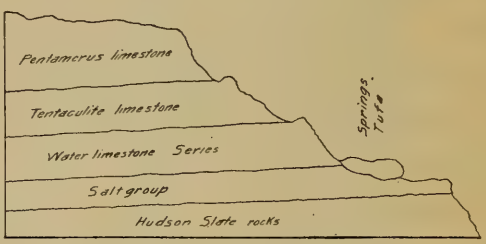

Fig. 1 Section at Sharon Springs, Schoharie county (After Mather 1843)

From its similarity to the Salina in western New York, the rock above the "Coralline" could be readily confused. But why the underlying shales, clearly resting on the Lorraine beds, were called Clinton was not explained. Mather[1] had already published a section at Sharon Springs, Schoharie co., where the Salina shales resting on the Lorraine beds and below the waterlime were designated as the Salt group, and Vanuxem[2] had shown the impossibility of any formation between the Salina and the Lorraine at the same place. He says: "The Onondaga salt group [Salina] and the Frankfort slate [Lorraine] are so near to each other, both being undisturbed, as to preclude every other deposit." Though Hall states that the "Coralline" could be traced continuously from Herkimer county to Schoharie, it is very evident from the above citations as well as from his own published sections,[3] that it could not be traced below the Salina, to which position it had been assigned. In each of the three sections herewith given between Sharon Springs and Litchfield,

[1] Geol. N. Y. 1st Dist. 1843. pl. 25, fig. 3.

[2] Geol. N. Y. 3d Dist. 1842. p. 79.

[3] Palaeontology of New York. 1852. 2:15. The first section given as in the town of Canajoharie, Montgomery co., must refer either to the section on Canajoharie creek, near Cherry Valley in Otsego county, or more probably to the section north of Cherry Valley near Salt Springville, as the highest beds in the town of Canajoharie are the Lorraine. Likewise the section above Wick's Store cited as in Montgomery, is in Herkimer county. This place is now known by the name of Deck.

Herkimer co., the Salina shales are given a position directly on the Clinton formation (*op. cit.*):

The following sections show the order of succession, and the nature of the materials of which the group is composed, at different localities, from its more easterly exposures to the Niagara river:

The most easterly section I have been able to observe is one in the town of Canajoharie, Montgomery co.; though the succession is there very obscure, and the whole thickness less than 50 feet.

1 Drab colored layers of Onondaga salt group
2 A red, coarse sandstone (forming a terrace) with pebbles, and containing much iron ore
3 A space occupied by shales
4 Grayish sandstone, conglomeritic below and darker colored and laminated above
(2–4: Clinton group)
5 Oneida conglomerate
6 Shales of Hudson river group

At Vanhornsville in the town of Stark, Herkimer co., the following section is exposed, though somewhat obscurely.

1 Onondaga salt group
2 Red, coarsely laminated, friable sandstone, containing much iron ore, but no distinct beds
3 Green shale with fossils
4 Red, diagonally laminated sandstone
5 Grayish sandstone and conglomerate, with thin layers of green shale
(2–5: Clinton group)
6 Oneida conglomerate
7 Shales and sandstones of the Hudson river group

Section above Wick's Store, in the town of Stark, Herkimer co.

1 Onondaga salt group
2 Quartzose sandstone and conglomerate, forming the terminating mass of the Clinton group
3 Thin bedded sandstone with fucoids, alternating with green shale
4 Red sandstone, diagonally laminated
5 White sandstone with pebbles and green shale
(2–5: Clinton group)
6 Oneida conglomerate
7 Shales of Hudson river group

In Herkimer county the "Coralline" is found in close proximity to the Eurypterus beds, which represent the upper part of the Salina. And it is singular that here, where the Salina has a considerable thickness, the relations of these beds should not have been at least suggested.

Vanuxem,[1] referring to the division line between the Salina and the Waterlime group in the eastern end of his district, represented by Oneida, Herkimer and Otsego counties, says: "There a brownish impure limestone is seen, often mottled, containing columnariae of a somewhat spherical form and about the size of an inch or more; also a few encrinital fragments, and a small orthocera, the species not named. This is the mass which separates the two groups, and forms the base of the Waterlime group."

Again[2] in speaking of the upper member of the Salt group, representing the Eurypterus-bearing bed of the Salina, he says: "Above the upper deposit there are irregular, light colored layers with globuliform columnaria and other fossils, which belong to the Waterlime group, or to an intermediate one which we do not attempt to establish." It may seem at first sight that Vanuxem might have meant by the intermediate layer that portion which we term Rondout, holding a position between the "Coralline" below and the Manlius limestone above. It will be seen however that the Waterlime group as defined by Vanuxem consisted, in this part of the State, of three distinct divisions, included between the Eurypterus-bearing beds of the Salina below and the Coeymans limestone above. The divisions of the Waterlime group as given by Vanuxem are as follows[3]: "The first or lowest portion consists of irregular layers with globuliform columnaria; above which there is a drab colored series, followed by the upper blue or dark colored ones."

The section as above given agrees essentially with the one at Schoharie, the lowest member corresponding with the "Coralline," the drab colored series with the Rondout and the uppermost blue or dark colored ones with the Manlius limestone. The only fossil mentioned by name as coming from the lower part of the

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[1] Geol. N. Y. 3d Dist. 1842. p. 111.
[2] Geol. N. Y. 3d Dist. 1842. p. 99.
[3] Geol. N. Y. 3d Dist. 1842. p. 112.

section was Globuliform columnaria, which undoubtedly is the same as Favosites niagarensis ? Hall. Other fossils are mentioned as occurring in the basal member, but they appear not to have been identified. Unfortunately, the studies of Vanuxem did not extend far east of Otsego county, and he did not correlate his sections in Otsego and Herkimer counties with those of Schoharie. It will thus be seen that, while Vanuxem recognized a section clearly above the Eurypterus beds in Herkimer county, he did not realize that the lowest member of his Waterlime group was the continuation of the "Coralline" of Schoharie county. On the other hand, Hall recognized the "Coralline" in both Schoharie and Herkimer counties, but in the latter he, evidently, was not aware of its position with reference to the Eurypterus beds.

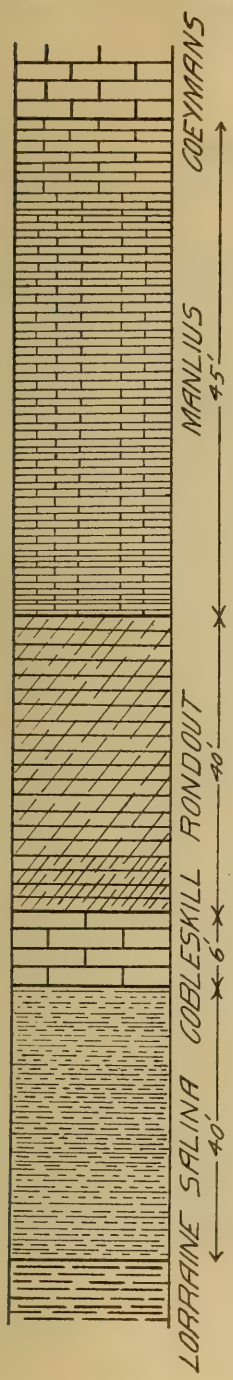

Fig. 2 Upper Siluric section at Howes Cave, Schoharie co.

The sections as above given, together with the results of a recent examination of the so called Clinton and Niagara formations extending from Schoharie into Herkimer county, clearly show that there is no representative of the Niagara east of Herkimer county; while the study of a new collection of fossils from Schoharie county and a similar examination of collections from horizons clearly above the Salina in western New York, conclusively demonstrate that the "Coralline" of Schoharie county is of an age later than the Salina, and that the "Coralline" has in New York State a greater extent than the Niagara itself.

The inappropriateness of the term Niagara as applied to the "Coralline" has been recognized for some time by Dr Clarke. This, together with the incongruity of the word Coralline as a

stratigraphic unit, has led him to substitute for these unsatisfactory designations the name Cobleskill,[1] as it is along this creek near Howes Cave that the outcrops of this limestone are most typical.

Section at Howes Cave

The accompanying section will serve to indicate the stratigraphic relations of the Cobleskill at Howes Cave. Directly beneath the Cobleskill the Salina shales are exposed with a thickness of 34 feet. The contact with the Lorraine beds can not be observed at this place, but in the bed of a small stream 1 mile farther north the contact is seen to be deceptively conformable. From observations made at this place, the thickness of the Salina at Howes Cave can not be far from 40 feet. The characters of these shales are quite uniform. In color they vary from a light gray to green. They break readily and soon crumple. The most conspicuous feature is the presence of nodular iron pyrites in such quantities that at Schoharie they were once mined. These shales have been quarried and sold for plaster, but, unlike beds of the Salina of western New York, they contain only traces of gypsum. Their value as a plaster seems to be due to the oxidation and decomposition of the iron pyrites, the sulfur of the pyrites combining with oxygen and water, forming sulfuric acid. The acid attacks the carbonate of lime present, forming lime sulfate, which, with the addition of two parts of water, gives gypsum.

Folding and slight displacements of these shales are often seen, specially near their lower portion. These, however, appear to be only local developments. There is no transition into the Cobleskill. The line of demarcation is very strongly defined. The soft shales, weathering away beneath, sometimes leave the Cobleskill as a projecting ledge. These same features are observed farther east at Schoharie, where the formation has a thickness of 27 feet, having thinned 13 feet in a distance of 5 miles. The most easterly extension of these shales that has been observed is near Gallupville, 5 miles east of Schoharie, showing that the extreme eastern extension of the great Salina beds of New York

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[1] U. S. N. Y. Sec. Rep't. Regents Bul. 59. 1902. p. r42.

Plate 2

Cobleskill limestone with underlying Salina shales at Howes Cave, Schoharie co.

can not be far from the town of Knox, Albany co., at which place it is quite likely that the Cobleskill slightly overlaps the Salina. Both of these formations are absent at Altamont a few miles farther east, and the Rondout is seen resting directly on the Lorraine beds.

Rondout waterlimes

Next above the Cobleskill is the Rondout waterlime, which at Howes Cave is 40 feet thick. The Rondout is transitional into the Manlius limestone above, as well as from the Cobleskill below. Hall[1] has called attention to the fact that, while in western New York, where the Manlius is absent, the line of demarcation between the Salina (=Cobleskill or "Bullhead" of Erie county) and the succeeding limestone (Onondaga) is very conspicuous, in eastern New York the Rondout, then regarded as the Salina, gradually gave way to conditions under which the Manlius limestone was formed. Regarding the "Bullhead" as Cobleskill, it will be seen that in New York, with the possible exception of Schoharie county, there appears to be no unconformity between the Salina and the overlying rock. The transition of the Rondout into the Manlius as observed in eastern New York is also to be noted at Cayuga lake, and these same conditions probably exist at least as far west as Seneca county, beyond which the Rondout and the Manlius have not been distinctly recognized.

The transition from Cobleskill to Rondout is marked by a change from the limestone of the Cobleskill to the cement of the Rondout. The weathered surface of the upper portion of the Cobleskill varies slightly from the weathered Rondout, but fresh fracture clearly shows the distinctive character of the cement rock. The fauna of the lower Rondout, though much reduced in force, is distinctively a Cobleskill fauna. Hall found Halysites catenulatus in the Rondout of Herkimer county, and recently Prof. J. J. Stevenson[2] called attention to the fact that Favosites niagarensis Hall is found abundantly in the lower 3 feet of the Rondout (cement) at Howes Cave. The

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[1] Palaeontology of New York. 1852. 2:339.
[2] N. Y. Acad. Sci. Ann. v. 13, no. 3, p. 365–66.

transition of the Rondout from the Cobleskill and the gradual passage into the Manlius were clearly recognized by Professor Stevenson, and, had he carried his observations a little farther, their true significance might have been realized. The gradual change from the Cobleskill, which he regarded as the Niagara, into the succeeding formations he explained by saying, "It is sufficiently evident that, while the great mass of Salina shales was in process of deposit in central New York and in much of the Appalachian region, the conditions within this portion of New York changed so gradually as to bring about only a slow disappearance of the fauna."

From similar observations, based on the section at Rondout N. Y., Messrs Ulrich and Schuchert[1] have correctly concluded that the so called "Clinton" of Schoharie county is really Salina. There is no doubt, however, that they did not properly construe the section at Rondout in assuming that the "Coralline" as there developed is equivalent to the Cobleskill of the Schoharie section. It will be shown from the sections in Ulster county that, while the Cobleskill is present, the "Coralline" of that region represents an age earlier than the Cobleskill. It may be here stated that, while Hall wrongly concluded as to the age and position of the Cobleskill in Schoharie county, he was more nearly right in his estimation of the age of the "Coralline" of Ulster county, though his conclusion in regard to the latter evidently was based on the Schoharie section.

Fossil localities of the Cobleskill in Schoharie county

The Cobleskill limestone is more or less fossiliferous throughout its extent in Schoharie county, and the following lists represent the collections made from its various outcrops. The sections will be taken up in order, beginning with the most easterly and extending along the line of outcrop into the western part of the county.

On the Stevens farm south of Shutter's Corners and 3 miles east of Schoharie the Cobleskill is partly exposed for some distance. This has proved to be the best collecting ground for

[1] N. Y. State Paleontologist. An. Rep't. 1901. p. 650 (foot note)

Cobleskill fossils that has yet been observed. The following species were obtained:

1 Acervularia (?) inaequalis *Hall*
2 Favosites niagarensis? *Hall*
3 Enterolasma caliculus *Hall*
4 Stromatopora concentrica *Hall*
5 S. constellata *Hall*
6 Atrypa reticularis *Linnè*
7 Camarotoechia neglecta *Hall*
8 Chonetes jerseyensis *Weller*
9 Orthothetes interstriatus *Hall*
10 Rhynchonella (?) lamellata *Hall*
11 R. pisum *Hall & Whitfield*
12 Spirifer crispus *var.* corallinensis *Grabau*
13 S. eriensis *Grabau*
14 Stropheodonta bipartita *Hall*
15 S. textilis *Hall*
16 Whitfieldella nucleolata *Hall*
17 Ilionia *cf.* canadensis *Billings*
18 I. galtensis *Whiteaves*
19 I. sinuata *Hall*
20 Mytilarca *sp.*
21 Pterinea securiformis *Hall*
22 P. subplana *Hall*
23 P. *cf.* subrecta *Hall*
24 Tellinomya equilatera *Hall*
25 Bellerophon (*large sp.*)
26 Bucania *sp.*
27 Murchisonia (?) terebralis *Hall*
28 M. *sp.*
29 Pleurotomaria *sp.*
30 Poleumita *cf.* crenulata *Clarke & Ruedemann*
31 Trochoceras gebhardi *Hall*
32 T. turbinatum *Hall*
33 Kionoceras darwini *Billings*
34 Orthoceras trusitum *Clarke & Ruedemann*
35 O. (*large*)
36 Cyrtoceras *sp. undet.*

37 Cornulites arcuatus *Conrad*
38 Beyrichia (*2 species*)
39 Calymmene camerata *Conrad*
40 C. niagarensis *Hall*
41 Dalmanites *sp. undet.*
42 Homalonotus *sp.*
43 Leperditia jonesi *Hall*
44 Lichas (Dicranogmus) ptyonurus *Hall*
45 Proetus *sp. undet.*

At this place the three system cleavage has caused the upper part of the rock at several points to become broken, so that the appearance is not unlike piles of pebbles. These pebbles often yield choice fossils of the smaller species, while the larger species are sometimes found in sections, being cut by the formation of cleavage planes. This method of weathering and in places the removal of the weathered material have left the harder portion, representing colonies of coral extending above the general surface of the rock. The appearance of these coral masses indicates that this was their original place of growth, and thus a locality favorable for the existence of other types of life illustrated by the fauna above given. That these coral beds were the habitat of many of these life forms is shown by the occurrence of Trochoceras gebhardi and large gastropods, resting on the summits of a coral growth. These gastropods, in turn, are seen to be places of attachment for new coral polyps, thus finally embedding the shells in the coral mass. Trochoceras gebhardi is also found as the nucleus of large concretions, the surrounding mass of which is made up largely of coral growth.

Below, in the more compact portion of the rock, there is a layer in which Chonetes jerseyensis Weller occurs in abundance. Associated with this species were found two fine specimens of Calymmene niagarensis Hall, the pygidium of Lichas (Dicranogmus) ptyonurus Hall, fragments of Homalonotus sp.; also a number of Proetus sp. and several specimens of the cosmopolitan brachiopod Atrypa reticularis Linn., which however is but rarely found in the Cobleskill. Fragments of a brachiopod which in general form

and surface markings strongly resembles Stropheodonta becki Hall have been found. They may however prove to be identical with S. textilis Hall.

Halfway between the above station and Schoharie at the spring which gives rise to a small brook, the Cobleskill is exposed for nearly its entire thickness. The following species were collected.

1 Favosites niagarensis ? *Hall*
2 Stromatopora concentrica *Hall*
3 Camarotoechia neglecta *Hall*
4 Rhynchonella (?) lamellata *Hall*
5 Spirifer crispus *var.* corallinensis *Grabau*
6 Whitfieldella nucleolata *Hall*

The outcrop on the hillside northeast of Schoharie has long been a favorite place for the collection of Cobleskill fossils. A number of years ago the Cobleskill was quarried here, principally for the construction of a stone wall at the foot of the hill. The following species have been identified from this quarry.

1 Favosites niagarensis ? *Hall*
2 Stromatopora concentrica *Hall*
3 Hederella *sp.*
4 Atrypa reticularis *Linn.*
5 Camarotoechia neglecta *Hall*
6 Orthothetes interstriatus *Hall*
7 Rhynchonella (?) lamellata *Hall*
8 Spirifer crispus *var.* corallinensis *Grabau*
9 Whitfieldella nucleolata *Hall*
10 Pterinea securiformis *Hall*
11 Bellerophon auriculatus *Hall*
12 Pleurotomaria ? subdepressa *Hall*
13 P. *sp.*
14 Spirorbis *sp.*
15 Trochoceras gebhardi *Hall*
16 T. turbinatum *Hall*
17 Cyrtoceras *sp.*
18 Orthoceras *sp. undet.*
19 Tentaculites *sp. undet.*
20 Calymmene camerata *Conrad*
21 Leperditia jonesi *Hall*

At Mix & O'Reilly's quarry the contact between the Lorraine and Salina beds can be favorably seen. The following section was measured with the aid of Mr O'Reilly.

	Feet
From the top of Lorraine to base of the Rondout.........	33
Cobleskill (partly obscured)...........................	6
Thickness of Salina shales............................	27
Thickness of Rondout...................................	17

Near the Brown quarry, ¼ mile southeast of the Schoharie postoffice, the Salina shales are exposed by the roadside. In the quarry there is exposed the basal member of the Cobleskill, 38 inches thick. This layer is hard and compact and except where weathered, fossils can be obtained from it only with difficulty. This layer is followed by one 16 inches thick, locally known as the marble layer on account of the beautiful polish which it takes. The marble layer is followed by thin layers 1 to 3 inches thick, having a somewhat sandy texture and quite fossiliferous. The following species were obtained from Brown's quarry.

1 Chaetetes *sp.*
2 Favosites niagarensis ? *Hall*
3 Stromatopora concentrica *Hall*
4 Fenestella *sp.*
5 Lichenalia *cf.* concentrica *Hall*
6 Camarotoechia neglecta *Hall*
7 Leptaena rhomboidalis *Wilck.*
8 Orthothetes interstriatus *Hall*
9 Rhynchonella ? lamellata *Hall*
10 Spirifer crispus *var.* corallinensis *Grabau*
11 Stropheodonta textilis *Hall*
12 Whitfieldella nucleolata *Hall*
13 Ilionia sinuata *Hall*
14 Pterinea securiformis *Hall*
15 Tellinomya aequilatera *Hall*
16 Pleurotomaria ? subdepressa *Hall*
17 Orthoceras *sp.*
18 Tentaculites *sp. undet.*
19 Beyrichia *sp. undet.*
20 Leperditia jonesi *Hall*

The faunas from the different layers vary somewhat. In the thin layers at the top Rhynchonella lamellata is

very abundant, and an undetermined species of Beyrichia occurs in large numbers. Chaetetes sp. and Tentaculites sp. undet. are also found in the thin layers. From the basal layer a single specimen of Leptaena rhomboidalis has been obtained. This species was also found at Clarke's cave west of Schoharie. It is however very rare in the Cobleskill of Schoharie county.

The following section will show the relation of the Cobleskill to the overlying rock as it is exposed in the nearly vertical wall of the Brown quarry.

	Feet	Inches
1 Thin bedded, light colored waterlime	..	10
2 Blue limestone	2	1
3 Blue limestone	2	1
4 Cement rock	4	2
5 Thin limestone layers, somewhat arenaceous	..	10
6 Limestone (marble layer)	1	4
7 Limestone (base of quarry)	3	2

giving the total thickness of 14 feet 6 inches. The three lower divisions represent the Cobleskill, being here exposed for a thickness of 5 feet 4 inches. The cement bed, together with the upper sections of the quarry, belongs to the Rondout.

One hundred yards south of Brown's quarry, Mr E. Vroman has opened recently a quarry in the blue limestone strata represented by 2 and 3 of the above section. The rock has a ragged fracture and is so brittle that large blocks can be quarried only with difficulty. Between the two strata there are many somewhat flattened forms of a large species of Favosites, much like F. helderbergiae Hall. They are generally incrusted in a covering of shaly material. When the upper layer is removed, the corals can be readily obtained. From the compact portion of the rock the following species were obtained.

1 Favosites niagarensis ? *Hall*
2 Stromatopora concentrica *Hall*
3 Camarotoechia neglecta ? *Hall*
4 Orthothetes interstriatus *Hall*
5 Rhynchonella lamellata *Hall*
6 Spirifer crispus *var.* corallinensis *Grabau*
7 Whitfieldella nucleolata *Hall*

8 Pterinea securiformis *Hall*
9 Orthoceras *sp.*
10 Beyrichia *sp.*
11 Leperditia *cf.* jonesi *Hall*

The above species so far as they can be determined, are forms which continued their existence from the Cobleskill up into the Rondout, indicating that the change was very gradual. The number of individuals found however is not large. Outside of the corals, Rhynchonella? lamellata and Leperditia cf. jonesi are the only species that can be readily obtained.

The southerly dip of the rocks brings the Cobleskill below the Schoharie valley, a short distance south of Vroman's quarry, but on the west bank of Schoharie creek, south of the bridge, it reappears together with the Salina and affords nearly a complete vertical section of these shales. The Cobleskill is exposed for its entire thickness, but is unfavorable for collecting.

One third of a mile north of the creek bridge at Clarke's cave, there is exposed a good section extending from the Lorraine shales to the Manlius limestone. From the Cobleskill there were obtained

1 Favosites niagarensis ? *Hall*
2 Leptaena rhomboidalis *Wilck.*
3 Orthothetes interstriatus *Hall*
4 Rhynchonella ? lamellata *Hall*
5 Spirifer crispus *var.* corallinensis *Grabau*
6 Stropheodonta textilis *Hall*

From the limestone layer above the cement bed of the Rondout at Clarke's cave the following species were obtained.

1 Favosites niagarensis ? *Hall*
2 Orthothetes interstriatus *Hall*
3 Rhynchonella ? lamellata *Hall*
4 Spirifer crispus *var.* corallinensis *Grabau*
5 Whitfieldella nucleolata *Hall*
6 Pterinea *cf.* securiformis *Hall*
7 Gastropod *sp.*

This fauna so far as it can be identified is made up entirely of Cobleskill species.

From Clarke's cave passing north along the eastern face of West mountain, the Cobleskill is obscured almost entirely by the great amount of talus, and about the only exposure is at the Strontianite mine, 1 mile north of Clarke's cave. Farther along, at the northeast point of West mountain, the Cobleskill is again partially exposed, and here the following species were collected.

1 Favosites niagarensis ? *Hall*
2 Orthothetes interstriatus *Hall*
3 Rhynchonella ? lamellata *Hall*
4 Spirifer crispus *var.* corallinensis *Grabau*
5 Stropheodonta textilis *Hall*
6 Whitfieldella nucleolata *Hall*
7 Ilionia sinuata *Hall*
8 Tellinomya aequilatera *Hall*
9 Murchisonia ? obtusa *Hall*
10 Pleurotomaria ? subdepressa *Hall*
11 Spirorbis *sp.*
12 Trochoceras gebhardi *Hall*
13 Gyroceras *sp.*
14 Oncoceras expansum *Hall*
15 Orthoceras *sp.* (large)
16 Phragmoceras corallophilum *Clarke*
17 Beyrichia (2 species)
18 Leperditia jonesi *Hall*
19 L. scalaris *Jones*

These specimens, as shown by the texture of the rock, are from the top or transitional layer of the Cobleskill. Here were found several specimens of Phragmoceras corallophilum Clarke, and associated with them were several species of gastropods and cephalopods and a very large brachiopod, all forms which had not before been observed from the Cobleskill. They are however too obscure to warrant even generic characters to be assigned to them. Several specimens of Leperditia scalaris Jones, were found at this station. These specimens exhibit in their left valves a nodule or dorsal "hump," while the right valves are without it. These and other features present show that these specimens are identical with L. scalaris

Jones, originally described from the Cobleskill or "Bullhead rock" of Erie county.

At the extreme northern end of West mountain, scarcely a mile southeast of Central Bridge, the Cobleskill is exposed in the bed of a small stream. Fossils were obtained as follows:

1 Favosites niagarensis ? *Hall*
2 Enterolasma caliculus *Hall*
3 Thysanocrinus *sp.*
4 Camarotoechia neglecta *Hall*
5 Rhynchonella ? lamellata *Hall*
6 Spirifer crispus *var.* corallinensis *Grabau*
7 Stropheodonta bipartita *Hall*
8 S. textilis *Hall*
9 Whitfieldella nucleolata *Hall*
10 Tellinomya aequilatera *Hall*
11 Bellerophon auriculatus *Hall*

There are no favorable exposures of the Cobleskill on the east side of the Cobleskill valley, but on the west side at Howes Cave it is finely exposed. At Howes Cave fossils are not readily obtained. The following were collected by the roadside near the old tunnel leading to the cement mine.

1 Favosites niagarensis? *Hall*
2 Stromatopora concentrica *Hall*
3 Rhynchonella ? lamellata *Hall*
4 Spirifer crispus *var.* corallinensis *Hall*
5 Whitfieldella nucleolata *Hall*
6 Ilionia sinuata *Hall*
7 Tellinomya aequilatera *Hall*

Well up in the cement bed above the Cobleskill at Howes Cave the following species were found.

1 Favosites niagarensis? *Hall*
2 Rhynchonella ? lamellata *Hall*
3 Spirifer crispus *var.* corallinensis *Grabau*

One mile northeast of Howes Cave the Lorraine is exposed in the bed of a small creek for a considerable distance. Above these the Salina shales are also exposed, affording a fine section well

up into the Rondout. The Cobleskill in this creek forms the brink of a waterfall. A hasty collection yielded the following species.

1 Acervularia ? inequalis *Hall*
2 Favosites niagarensis ? *Hall*
3 Stromatopora concentrica *Hall*
4 Camarotoechia neglecta *Hall*
5 Spirifer crispus *var.* corallinensis *Grabau*
6 Whitfieldella nucleolata *Hall*
7 Ilionia sinuata *Hall*

One half mile beyond the above station on the farm of Mr Tarr, there are a number of large boulders from which corals may be obtained in abundance.

1 Acervularia ? inequalis *Hall*
2 Diplophyllum coralliferum *Hall*
3 Halysites catenulatus *Linn.*
4 Favosites niagarensis? *Hall*
5 Stromatopora concentrica *Hall*
6 S. constellata *Hall*
7 Spirifer crispus *var.* corallinensis *Grabau*
8 Whitfieldella nucleolata *Hall*
9 Ilionia sinuata *Hall*
10 Tellinomya aequilatera *Hall*

From this point the Cobleskill is covered by drift for more than a mile, but it again is exposed by the roadside and on the farm at Eugene Maxwell's, and from here exposures are frequent on the way to Grovenor's Corners, where the Salina is also exposed. All these outcrops of the Cobleskill are fossiliferous, and the collections contain all the common forms and several specimens of a species of Dalmanites. The Cobleskill is readily traced from Grovenor's Corners to Carlisle, and at a distance of ½ mile northwest of the village it has been quarried for inclosure walls. The Salina shales crop out by the roadside a short distance beyond.

Species as follows were collected from the quarry.

1 Chaetetes *sp.*
2 Enterolasma caliculus *Hall*
3 Favosites niagarensis? *Hall*

4 Stromatopora concentrica *Hall*
5 Trematopora *sp.*
6 Camarotoechia neglecta *Hall*
7 Orthothetes interstriatus *Hall*
8 Spirifer crispus *var.* corallinensis *Grabau*
9 Stropheodonta bipartita *Hall*
10 S. textilis *Hall*
11 Whitfieldella nucleolata *Hall*
12 Ilionia sinuata *Hall*
13 Tellinomya aequilatera *Hall*
14 Pleurotomaria ? subdepressa *Hall*
15 Trochoceras gebhardi *Hall*
16 Orthoceras *sp.*
17 Beyrichia *sp.*

There is another exposure of the Cobleskill near Sharon and also one 3 miles east of Sharon Springs from which fossils may be obtained. These are the last exposures of the Cobleskill in Schoharie county from which collections were made. The Cobleskill is undoubtedly present at Sharon Springs, but I did not find any outcrops.

The following is a complete list of fossils which thus far have been observed from the Cobleskill of Schoharie county.

1 Acervularia ? inequalis *Hall*
2 Diplophyllum coralliferum *Hall*
3 Enterolasma caliculus *Hall*
4 Favosites niagarensis? *Hall*
5 Halysites catenulatus *Linn.*
6 Stromatopora concentrica Hall
7 S. constellata *Hall*
8 Chaetetes *sp.*
9 Fenestella *sp.*
10 Hederella *sp.*
11 Lichenalia *cf.* concentrica *Hall*
12 Trematopora *sp.*
13 Thysanocrinus *sp.*
14 Atrypa reticularis *Linne*
15 Camarotoechia neglecta *Hall*
16 Chonetes jerseyensis *Weller*

17 Leptaena rhomboidalis *Wilck.*
18 Orthothetes interstriatus *Hall*
19 Rhynchonella (?) lamellata *Hall*
20 R. pisum *Hall & Whitfield*
21 Spirifer crispus *var.* corallinensis *Grabau*
22 S. eriensis *Grabau*
23 Stropheodonta bipartita *Hall*
24 S. textilis *Hall*
25 Whitfieldella nucleolata *Hall*
26 Ilionia *cf.* canadensis *Bill.*
27 I. galtensis *Whiteaves*
28 I. sinuata *Hall*
29 Mytilarca *sp.*
30 Pterinea securiformis *Hall*
31 P. subplana *Hall*
32 P. subrecta *Hall*
33 Tellinomya equilatera *Hall*
34 Bellerophon auriculatus *Hall*
35 Bucania *sp.*
36 Murchisonia ? terebralis *Hall*
37 Pleurotomaria ? subdepressa *Hall*
38 P. *sp. undet.*
39 Poleumita *cf.* crenulata *Clarke & Ruedemann*
40 Spirorbis *sp.*
41 Trochoceras gebhardi *Hall*
42 T. turbinatum *Hall*
43 Cyrtoceras *sp.*
44 Gyroceras *sp.*
45 Kionoceras darwini *Billings*
46 Oncoceras expansum *Hall*
47 Orthoceras trusitum *Clarke & Ruedemann*
48 O. *large sp.*
49 Phragmoceras corallophilum *Clarke*
50 Cornulites arcuatus *Conrad*
51 Tentaculites *sp. undet.*
52 Beyrichia (*2 species*)
53 Calymmene camerata *Conrad*
54 C. niagarensis *Hall*
55 Dalmanites *sp.*

56 Homalonotus *sp.*
57 Leperditia jonesi *Hall*
58 L. scalaris *Jones*
59 Lichas (Dicranogmus) ptyonurus *Hall*
60 Proëtus *sp. undet.*

Vertical range of the species of the Cobleskill fauna of Schoharie county

	Cobleskill of Schoharie co.	Cobleskill of western New York	Cobleskill[1] of eastern New York	Guelph	Niagara	Rondout
Acervularia ? inequalis	×		×			
Diplophyllum coralliferum	×					
Enterolasma caliculus	×			×	×	
Favosites niagarensis?	×	×			?	×
Halysites catenulatus	×	×	×	×	×	×
Stromatopora concentrica	×	×	×	×	×	×
S. constellata	×					
Lichenalia *cf.* concentrica	×				×	
Atrypa reticularis	×		×		×	
Camarotoechia neglecta	×		×	×	×	?
Chonetes jerseyensis	×	×	×			
Leptaena rhomboidalis	×		×		×	
Orthothetes interstriatus	×		×			×
Rhynchonella ? lamellata	×		×			×
R. pisum	×	×	×		×	
Spirifer crispus var. corallinensis	×	×	?	?		×
S. eriensis	×	×				
Stropheodonta bipartita	×	×	×			
S. textilis	×	×				
Whitfieldella nucleolata	×		×			×
Ilionia *cf.* canadensis	×			×		
I. galtensis	×			×		
I. sinuata	×	×				
Pterinea securiformis	×					×
P. subplana	×	?		×	×	
P. subrecta	×					
Tellinomya equilatera	×					
Bellerophon auriculatus	×					
Murchisonia ? terebralis	×					
Pleurotomaria ? subdepressa	×	×				
Poleumita *cf.* crenulata	×			×		
Trochoceras gebhardi	×			×		
T. turbinatum	×					
Kionoceras darwini	×			×	×	
Oncoceras expansum	×					
Orthoceras trusitum	×			×		
Phragmoceras corallophilum	×					
Cornulites arcuatus	×			×	×	
Calymmene camerata	×		×			
C. niagarensis	×		×		×	
Leperditia jonesi	×					
L. scalaris	×	×				

[1] Includes also fossils from the lower zones of the Decker Ferry formation and the Wilbur limestone ("Coralline" of Hall), which are below the Cobleskill.

In the beginning of this paper I have called attention to the fact that the original fauna from the "Coralline" limestone as described by Hall contained but little that was truly Niagaran in character. An examination, however, of the above list will show that the species which are known to occur outside of the Cobleskill limestone are largely Niagaran species. In this case, however, these species are not indicative of the age of the Cobleskill, but must be looked on as the return of the Niagara and Guelph faunas after the long interval during which the Salina shales of central New York were deposited, and during which these faunas suffered such changes as time and environment would produce.

A number of Cobleskill species continued their existence into the Rondout; and, so far as they have been observed, all the species that have been found near the base of the Rondout, with the exception of the Eurypterus, are forms also found in the Cobleskill, but none of the gastropods or cephalopods of the Cobleskill appear to pass upward into the Rondout.

Cobleskill section at Union Springs, Cayuga lake

The studies of Vanuxem extended as far west as Cayuga lake, the western limit of the third district. The last place where a line is sharply drawn between the Salina and the Waterlime recognized as consisting of three groups, is at Waterville, in Oneida county. From that place to Cayuga lake only one locality is mentioned where the brownish limestone, so characteristic of the base of his Waterlime group in the eastern end of the district, follows the Salina. This locality is near Jamesville, in Onondaga county. A number of quarries are mentioned about Cayuga lake, and a final disappearance of the group under the lake. The stratigraphic position of these quarries, however, is not clearly indicated.

In this connection it is interesting to note that Hall in speaking of the fourth or upper deposit of the Salina group, says:[1]

In Seneca county it does not appear in its usual characters; the highest rock of the group being a fine grained, dark colored, and grayish brown mass, which apparently represents the lower part

[1] Geol. N. Y. 4th Dist. 1843. p.129.

of this division. Between this and the succeeding limestone, there is an interval which is probably occupied by this mass, but too deeply covered to be visible. It appears on the east side of Cayuga lake, coming down to the shore.

As will be shown later, the grayish brown mass represents the Cobleskill, the covered interval the Rondout and the succeeding limestone the Manlius.

Attention was first prominently called to the section under consideration by the late Prof. S. G. Williams, in a *Note on the Lower Helderberg Rocks of Cayuga Lake*[1] and in a paper on "The Western Extension of Rocks of Lower Helderberg Age in New York", published in the *American Journal of Science*.[2] The section studied by Williams was in the vicinity of Union Springs and was included between the gypsum beds of the Salina and the Oriskany sandstone. From this section, having according to Williams a thickness of about 65 feet, he gives a list of 26 fossils, a number which were, according to the identifications, representatives of the Coeymans limestone and the New Scotland beds. It is evident, however, that Williams did not examine the upper horizons of this section that lie directly beneath the Oriskany sandstone, or he could hardly have failed to find a nearly typical Manlius limestone fauna and thus perhaps have reached a different conclusion as to the nature of the fauna about Union Springs. Though Williams in his determinations of the fossil forms seems to have been supported by such authorities as Hall and Whitfield, there can be no longer any doubt that the fauna was not properly construed in assuming any definite biologic or stratigraphic relation to the Helderbergian series.

The distinctively Siluric aspect of this fauna was first established by Dr Clarke,[3] who has also given considerable attention to the stratigraphy about Union Springs, which has resulted in accurately determining the position in the rock series of the outcrops on Frontenac island, from which the fauna of this section is mainly obtained. The accompanying map showing the geologic relations about Union Springs has been prepared by Dr

[1] 6th An. Rep't. N. Y. State Geologist. 1897. p. 10–12.
[2] Ser. 3. 1886. 31:139–45.
[3] N. Y. State Mus. Mem. 3. 1900. p.99–101.

SECTIONS TO ILLUSTRATE THE STRATIGRAPHY
OF
BECRAFT MOUNTAIN
COLUMBIA COUNTY NEW YORK
BY
AMADEUS W. GRABAU
1903

LEGEND

Onondaga | Schoharie | Esopus | Oriskany | Port Ewen | Becraft | New Scotland | Coeymans | Manlius

HUDSON RIVER GROUP

Horizontal and Vertical Scale

Clarke and Mr D. D. Luther, and it is with their permission that it is inserted in this paper.

The collections from the waterlimes of western New York by Mr Luther and notes bearing on the region examined, have been made available for my study and have given valuable suggestions in working out the relations of the Cobleskill. The study of the fauna from Frontenac island (Union Springs) and its comparison with the fauna of the Cobleskill of Schoharie county have had a very important bearing in showing that the "Coralline" or Cobleskill of Schoharie county is of post-Salina age. That a probable relationship existed between these two rock masses had already been suggested by Dr Clarke. In speaking of the species associated with the Eurypterus in the Salina beds of Cayuga and Herkimer counties, he says:[1]

The study of these has indicated the probability that we may not be altogether secure in the time-honored interpretation and correlation of some of our other strata having similar lithologic characters, such for example as the Coralline limestone of Schoharie county and the waterlimes of the eastward sections. The fauna of a specially interesting outcrop of dark dolomite appearing on Frontenac island in Cayuga lake, where it is intercalated between the Waterlime strata, will, when fully studied, give important aid in the interpretation of the proper relations of these beds to those which they immediately precede in time and to which they are otherwise allied, that is to the true Helderbergian strata.

The probability of a relation existing between the beds of Frontenac island and the Cobleskill of Schoharie county, as thus expressed, may now be considered a certainty. As already indicated, the result given by Dr Clarke, relative to the unmistakable Siluric aspect of the section at Union Springs, is confirmed by a reexamination of the fauna, of which the stratigraphic relations, as shown by the accompanying map, can leave no doubt as to the position of these rocks with reference to the true Helderbergian strata.

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[1] N. Y. State Paleontologist. An. Rep't. 1902. p. 422.

Frontenac island

The best location for the collection of Cobleskill fossils in the vicinity of Union Springs is on Frontenac island in Cayuga lake, about ½ mile from the village. This island, having an area of one half acre, is the remaining part of the south limb of an anticline, which has its axis extending in a direction a little north of east and passing through Hibiscus point, ¾ of a mile north of the island. The upward flexure of the strata at Hibiscus point brings the gypsum beds above the lake level, but the dip on the north side of the anticline makes them again disappear below the lake at a point opposite the railroad junction.

The surface of the island is nearly level and extends about 6 feet above the lake.

The outcrops of the Cobleskill on the island consist of three strata of hard, dark magnesian limestone, having a dip to the south of about five hundred feet to the mile, thus bringing into view the three layers, which together have a thickness of 8 feet, 6 inches. The upper layer, which is soft and quite dark, has a thickness of 3 feet, 2 inches and breaks readily into small angular fragments. With the exception of corals it is the most fossiliferous layer. The middle layer which is 2 feet, 10 inches thick, contains Stromatopora in abundance and, except that the color is a little darker, it is precisely the same in appearance as the Stromatopora bed of the Manlius limestone, holding a position 60 feet higher. The two upper layers are quite uniform in color, which is well retained even after they have been exposed for a considerable length of time. The lower layer, with a thickness of 2 feet, 6 inches, weathers a lighter color than the upper layers, is less fossiliferous and approaches more closely the character of the underlying Eurypterus beds.

The Cobleskill limestone where exposed on the mainland is also fossiliferous, but no species were found that do not occur on the island. The following list therefore represents species identified from Frontenac island.

1 Chaetetes (Monotrypella) arbusculus *Hall*
2 Favosites niagarensis? *Hall*
3 Halysites catenulatus *Linn.*

4 Stromatopora concentrica *Hall*
5 Cyathophyllum hydraulicum *Simpson*
6 Crinoid *sp.*
7 Chonetes jerseyensis *Weller*
8 C. undulata *Hall*
9 Rhynchonella pisum *Hall & Whitfield*
10 Spirifer crispus *var.* corallinensis *Grabau*
11 S. vanuxemi *Hall*
12 Stropheodonta bipartita *Hall*
13 S. textilis *Hall*
14 S. varistriata *Con.*
15 Whitfieldella sulcata *Van.*
16 Ilionia sinuata *Hall*
17 Megambonia aviculoidea *Hall*
18 Pterinea subplana? *Hall*
19 Bucania *sp.*
20 Cyclonema *sp.*
21 Loxonema *sp.*
22 Trochoceras gebhardi *Hall*
23 Pleurotomaria ? subdepressa *Hall*
24 Tentaculites gyracanthus *Eaton*
25 Gomphoceras septoris *Hall*
26 Orthoceras trusitum *Clarke & Ruedemann*
27 Orthoceras *large sp.*
28 Beyrichia *sp.*
29 Leperditia alta ? *Hall*
30 L. *cf.* scalaris *Jones*

Distribution of the fauna from Frontenac island

	Cobleskill at Cayuga lake	Cobleskill, Schoharie co.	Guelph	Manlius	Cobleskill at Buffalo
Chaetetes (Monotrypella) arbusculus	×			×	
Favosites niagarensis?	×	×			?
Halysites catenulatus	×	×			
Stromatopora concentrica	×	×	×		
Cyathophyllum hydraulicum	×				×
Chonetes jerseyensis	×	×			
C. undulata	×				
Rhynchonella pisum	×	×			
Spirifer crispus *var.* corallinensis	×	×	?		
S. vanuxemi	×			×	
Stropheodonta bipartita	×	×			
S. textilis	×	×			
S. varistriata	×			×	
Whitfieldella sulcata	×			×	×
Ilionia sinuata	×	×		×	
Megambonia aviculoidea	×			×	
Pterinea subplana?	×	×	×		
Trochoceras gebhardi	×	×	×		×
Pleurotomaria ? subdepressa	×	×			
Tentaculites gyracanthus	×			×	
Gomphoceras septoris	×		×		
Orthoceras trusitum	×	×	×		
Leperditia alta?	×			×	
L. *cf.* scalaris	×	×			×

The Cobleskill limestone appearing on Frontenac island also outcrops at the south end of Howland's point, ¼ mile northeast of the island. The dip here is greater than on the island and the outcrop less favorable for collecting. The surface layers however contain large white Favosites, making a strong contrast with the dark color of the limestone. The surface as here exposed is in places polished and grooved by glacial action, thus indicating its resistant nature. A short distance from this outcrop on the northwest end of Howland's point there is an outcrop of the Salina waterlime carrying Eurypterus and an undescribed species of Lingula. This outcrop of the Salina shows that the beds of Cobleskill on Frontenac island immediately overlie the Eurypterus beds of the Salina.

The Cobleskill limestone is also exposed in O'Connor's old quarry 1½ miles northeast of the island. The section in this

quarry shows 6 feet of Salina waterlime, with 4 feet, 8 inches of Cobleskill. The Stromatopora layer forms the upper surface of the Cobleskill.

The location of this quarry is about 85 feet above the lake, which shows that the average dip of the Cobleskill is about 120 feet a mile. It should be noticed however that in this region the dip varies greatly. This is due largely to the fact that the flexures of the strata have been produced by two sources and at different times. One set of flexures evidently is produced by horizontal pressure resulting in a general tilting of the rocks, the other by vertical pressure from below producing local disturbances, sometimes locally counteracting the effect of the general tilting of the strata and sometimes producing low conical elevations, showing that the pressure was applied at a single point.

The pressure producing these local disturbances appears to be due to the increase in bulk of the underlying beds, in the formation of gypsum from its anhydrite. These beds of gypsum appear to be forming at the present time and they offer other interesting features, which can not be considered here. Excellent examples of these local disturbances can be seen in the field just north of O'Connor's quarry, where the Cobleskill is elevated into two cones, each having an elevation of 6 feet at the apex, where the rock is much broken and fissures are seen radiating from the center.

A short distance northeast of O'Connor's old quarry and at 15 to 20 feet higher there is another quarry in which 8 feet of Rondout waterlime is exposed. It will be seen from the position of these two quarries that the Cobleskill here holds the same position that it does in Schoharie county, namely, above the Salina and below the Rondout. The waterlime exposed in this quarry appears to be a good cement rock. It is dark in color, shows faint lines of deposition, and a tendency to split along these lines. A single segment of Eurypterus was found in the waterlime exposed in this quarry.

The Cobleskill limestone again appears in the old quarry on the land of Mr John Wooley, about ¾ of a mile south of Cross Roads. The part of the limestone which is exposed, is hard, dark

in color and has a thickness of 4 feet. The Stromatopora bed forms the upper surface. Below the Cobleskill there is exposed 12 to 15 feet of Salina waterlime, which becomes laminated and shaly on exposure. In the Salina a short distance below the Cobleskill, Lingula sp. undet. occurs.

A cut on the Lehigh Valley Railroad, 1/4 of a mile east of Cross Roads station, passes through beds of gypsum at what is known as the Thompson quarry. Above the gypsum in the banks east of the pit, there are about 25 feet of Salina waterlime, overlain by the Cobleskill, which is here much folded and broken. The upper part of the Cobleskill is covered, but the overlying dark Rondout waterlime shows slightly in the top of the cut on the south side and in the field above. Near the middle of the Salina waterlime in this cut fossils are quite abundant. Several species of brachiopods and fragments of Eurypterus occur. The Lingula sp. undet. already mentioned as associated with the Eurypterus at Howland's point, is found here extending to near the base of the waterlime. With the exception of a species of Leperditia, this Lingula appears to be the lowest fossil above the gypsum beds.

The elevation of the Cobleskill in this cut is 510 feet A. T., which is 120 feet higher than Frontenac island. This outcrop in the cut however is on the other limb of the anticline, with a dip strongly toward the northwest, showing that the actual dip of the rocks is much greater than the above figures would seem to indicate.

Manlius limestone at Union Springs

The best exposure of the Manlius limestone in the vicinity of Union Springs is in the J. S. Shaliboo quarry, 1 mile south of the village. The part of the Manlius that is exposed is directly below the Oriskany sandstone. The upper layer of the Manlius is 4 feet 5 inches thick and quite free from Stromatopora, but Leperditia alta Hall and a small species of Tentaculites are very abundant. The next layer below is a fine, dark blue limestone containing much Stromatopora. This is the layer which in appearance is similar to the middle layer of the Cobleskill on Frontenac island, to which reference already has been

made. The third layer contains less Stromatopora, while in the fourth layer it is absent. The lower layers weather nearly a uniform color. The following species have been identified from this quarry.

1 Chaetetes (Monotrypella) arbusculus *Hall*
2 Stromatopora *sp.*
3 Orthothetes interstriatus *Hall*
4 Spirifer vanuxemi *Hall*
5 Stropheodonta varistriata *Con.*
6 Whitfieldella laevis *var.* ?
7 W. sulcata *Van.*
8 Holopea antiqua *Van.*
9 Tentaculites *sp.*

Cobleskill in Seneca and Ontario counties

In going west from Union Springs the same stratigraphic relations continue over the eastern part of Seneca county, but in McQuan's quarry, 1½ miles southwest of Seneca Falls, there is a bed of waterlime lying directly below the Oriskany sandstone. This stratum of waterlime, which is 11 feet thick, contains Eurypterus within 2 feet of the Oriskany and represents the Rondout. Below the Rondout there is a bed of dark blue limestone containing much Stromatopora in its upper part but much less near the base. This layer is 8 feet thick and much like the Cobleskill exposed on Frontenac island, to which formation it is referred. The Salina beds do not appear at this point, but at Seneca Falls the gypsum beds are overlain by Salina waterlime containing Eurypterus. The Stromatopora bed of the Cobleskill is covered at Seneca Falls, but it is evident from the position of these two sections that it is included between the Eurypterus bed of the Salina and the Rondout.

Whether the Manlius limestone again appears west of Seneca Falls has not been satisfactorily established, though there are several localities where beds somewhat similar to the Manlius limestone have been observed. Hall[1] mentions but a single locality west of Cayuga lake, where fossils characteristic of the Man-

[1] Geol. N. Y. 4th Dist. 1843. p.141–42.

lius limestone were found. This locality is in the town of Phelps, Ontario co. The thin layers in which the fossils occur are said to be directly above the Salina waterlime. The upper limit of the Salina as here given by Hall is not clear, since in Seneca county and at Union Springs the Cobleskill and the Rondout were included in the Salina. The fossils obtained by Hall from this locality were not well preserved, and the figures given are illustrations of typical Manlius limestone fossils from central New York and not of those that were obtained in Ontario county.

Whatever the stratigraphic relations of these beds may be in the vicinity of Phelps, it is evident that, before the western limit of the county is reached, there is found a stratum similar to the "Bullhead", lying directly below the Oriskany or below the Onondaga, where the Oriskany is lacking, and that it occurs in this position at a number of points between Ontario county and Buffalo, at which it is better known than at any other locality.

Cobleskill, or "Bullhead" limestone, of Erie county

The quarries of the Buffalo Cement Co. afford excellent exposures of the Cobleskill or "Bullhead" magnesian limestone. The Cobleskill lies directly above the Eurypterus-bearing beds of the Salina and is transitional from them. According to a recent paper by Mr Schuchert[1] there is a hiatus between the Eurypterus-bearing beds of the Salina and the "Bullhead" rock of Erie county. It is very evident however that the rocks between which the hiatus is said to occur are transitional, and that such a hiatus does not exist, nor would one have been considered by Mr Schuchert had he correlated the "Bullhead" with the Cobleskill instead of with the Manlius.

The upper surface of the Cobleskill at Buffalo is very irregular, evidently because of elevation and erosion during the interval extending from Cobleskill and lasting till late Oriskany time. Another feature of the Cobleskill at Buffalo is the deep vertical fissures, extending through its entire thickness and well down into the cement beds of the Salina. Attention has already been called to similar fractures in the Cobleskill about Union Springs.

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[1] U. S. Mus. Proc. 1902. 26:416.

Whether they were produced by similar causes, it is at present impossible to say. Grabau has expressed the opinion that those at Buffalo are probably due to an earthquake shock. Some of the fractures at Union Springs appear to be of recent origin, while those described from Buffalo must have been formed previ-

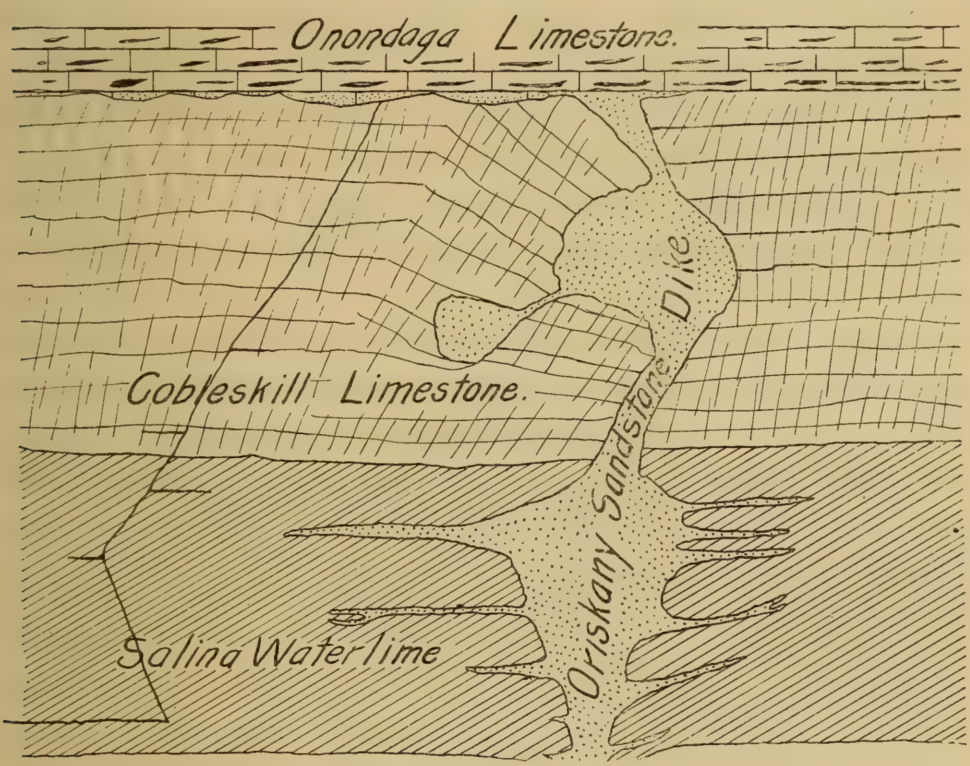

Fig. 3 Dike through Cobleskill limestone, Buffalo cement quarry (after Clarke)

ous to Oriskany deposition, since they are filled with sand typical of the Oriskany. The dikes in the Cobleskill at Buffalo have been described in detail by both Dr Clarke[1] and Dr Grabau.[2]

The stratum of Salina waterlime that is burned for "hydraulic cement" at Buffalo is slightly more than 5 feet thick. It contains a number of species of Eurypterus and a species of Lingula, apparently the same that is associated with the Eurypterus at Union Springs. There are also a number of other species of fossils described from the cement bed.

The character of the Cobleskill limestone varies considerably in its extent in New York State. In Schoharie county, where corals are so abundant that often they make up a large portion

[1] N. Y. State Mus. Mem. 3. 1900. p.96–98.
[2] Geol. Soc. Am. Bul. 1900. 11:357–61

of the rock, it is a limestone. In the western sections, where the corals common to the eastern portion are very rare, it is a dolomite. The petroleum odor so characteristic of the Cobleskill in Erie county is not observed in the eastern sections. In Erie county the rock is filled with cavities, due to the dissolving out of the corals, but in Schoharie county the corals often appear to be the most resistant portion of the rock. In both sections the Cobleskill is in some portions rich in iron pyrites. In the three sections where the Cobleskill has been mainly studied it varies but little in thickness; at Buffalo it is 8 feet, 4 inches, at Union Springs 8 feet, 6 inches and in Schoharie county it averages 6 feet.

In view of our present studies, the most interesting feature of the Cobleskill of Erie county is the fauna which it contains. Of this fauna a careful study has been made by Dr A. W. Grabau.[1] From this limestone he recognized 12 species, to which has been added a species of Favosites. The following species have been identified from the Cobleskill of Erie county.

1 Nematophyton crassum *Penhallow*
2 Cyathophyllum hydraulicum *Simpson*
3 Favosites *sp.*
4 Orthothetes interstriatus Hall (= O. hydraulicus *Whitfield*)
5 Spirifer eriensis *Grabau*
6 Whitfieldella sulcata *Van.*
7 W. nucleolata *var.*
8 W. *cf.* laevis *Whitfield*
9 Rhynchonella *sp.*
10 Loxonema ?
11 Pleurotomaria ?
12 Trochoceras gebhardi *Hall*
13 Leperditia scalaris *Jones*

A rather minute analysis of this fauna convinced Dr Grabau that it was closely related to the fauna of the Cobleskill, or "Coralline", limestone of Schoharie county, a conclusion which is strengthened by a recent comparison of the two faunas. The following species are common to the Cobleskill of Erie and Scho-

[1] Buffalo Geol. Soc. 1900. 11:351–55, 363–73.

harie counties. Orthothetes interstriatus Hall, Spirifer eriensis Grabau, Trochoceras gebhardi Hall, Leperditia scalaris Jones. Two species, Cyathophyllum hydraulicum Simpson and Whitfieldella sulcata Van., occurring in the Cobleskill in Erie county, are also found in the Cobleskill at Union Springs.

In the study of this fauna Dr Grabau obtained a good clue, which if followed would undoubtedly have enabled him to establish the true position of the Cobleskill, or "Coralline", of Schoharie county. Having followed however Hall's correlation of the "Coralline" as the eastern representative of the Niagara, he concluded "that the Manlius (= Cobleskill) limestone fauna of the Niagara region is a late return of the Coralline limestone fauna, at the close of the long interval during which the Salina shales were deposited in the Siluric seas of this region."

Cobleskill of the Hudson river valley

In the opening sentence of the original description of the "Coralline" limestone Hall[1] briefly refers to its occurrence in the Hudson river valley as follows: "In the neighborhood of Schoharie, and extending along the base of the Helderberg mountains and along the Hudson river, there is a thin mass of limestone, characterized by an immense number of corals, chiefly favosites, and which forms a band so distinct from any other limestone that it has been for many years known by this name." Hall[2] makes another reference to the presence of this limestone in the Hudson river valley; he says "The Coralline limestone exists in place at several localities on the east side of the Helderberg, but I have had no opportunity of examining these places in detail. It is not improbable that many more species may be added to those already known."

The fauna of this limestone in the Hudson river section however remained unstudied. Darton has given us much relative to the occurrence of this limestone in Greene and Ulster counties, Dale and Davis have each made mention of its presence in the quarries about Rondout where it is typically developed, but, so

[1] Palaeontology of New York. 1852. 2:321.
[2] Palaeontology of New York. 1852. 2:337.

far as I am aware, it has always been considered the equivalent of the Cobleskill, or "Coralline", limestone of Schoharie county.[1]

Upper Siluric section at Rondout

The following section at Rondout, from about the middle of "the Vlightberg", was measured with the aid of Mr P. E. Clark, mine superintendent of the Newark Lime & Cement Co. Included between the Coeymans limestone above and the Lower Siluric (= Normanskill?) shales we have:

	Feet	Inches
1 Manlius. Three layers of thin laminated limestone, representing the "Ribbon limestone" of some of the older writers	12	7
2 Manlius. Stromatopora layer	7	6
3 Manlius. Banded limestone	5	5
4 Manlius. Three layers of dark, thin bedded limestone. Spirifer vanuxemi and Tentaculites gyracanthus are found in the basal member	12	
5 Rondout. The "paving block"	7	5
6 Rondout. The "prismatic" layer. Makes a good cement, but, together with the underlying Leperditia bed, it is usually left to form the hanging wall	4	8
7 Rondout. Limestone containing Leperditia	2	2
8 Rondout. Impure layer of cement known as the "curly"	1	5
9 Rondout. Soft "gray cement"	3	1
10 Rondout. Hard "gray cement"	5	
11 Cobleskill limestone		7
12 Salina. Hard "black cement"	5	6
13 Salina. Soft "black cement"	4	5
14 Salina. Wilbur limestone (= Niagara or "Coralline" limestone of Hall and other authors)	7	
Total	78	9

[1] I am indebted to Mr Gilbert van Ingen for much information relative to the geology of the sections studied in Ulster county.

The thicknesses by formations are as follows:

	Feet	Inches
The Manlius	37	6
The Rondout	23	9
The Cobleskill		7
The Salina, including basal limestone	16	11

I have already, in a previous paragraph, called attention to the fact that the position of the "Coralline" limestone at Schoharie, as determined by Messrs Ulrich and Schuchert, is said to have been based on the section at Rondout N. Y. In making this determination, however, these distinguished workers in paleontology followed Hall's correlation of this "Coralline" bed as the equivalent of the Cobleskill, or "Coralline," of Schoharie county, an obvious error now that it is known that in Ulster county the Cobleskill belongs to a higher horizon than the so called "Coralline", and consequently the "Coralline" of the Hudson river valley really belongs to an earlier age.

Starting from the type locality of the Cobleskill in Schoharie county, where its stratigraphic relations to the overlying formations are accurately known, the Manlius limestone can be traced continuously across the Helderberg and into Ulster county. In a like manner, the Rondout at the base of the Manlius can be traced, but it is not always so conspicuous, and specially in the Helderberg it has become very thin, still in Albany county at Altamont, Indian Ladder, New Salem and South Bethlehem it can be observed, and, since the Cobleskill and the Salina have thinned out, it rests directly on the Lorraine shales. Similar stratigraphic conditions exist in the vicinity of Catskill, Greene co., and southward from this place the Rondout becomes better developed, and good exposures are seen just north of West Camp in the cut of the West Shore Railroad.

In Schoharie county the basal portion of the Rondout lying directly on the Cobleskill is burned for "hydraulic" cement, but in passing eastward over the Helderberg this cement bed thins out and is wanting for many miles. It comes in again before Ulster county is reached, and here, as in Schoharie county, it represents the basal portion of the Rondout as here defined. Throughout Ulster county this basal portion of the Rondout is

known as the "gray cement." Directly beneath the Rondout, or "gray cement," the Cobleskill is found. The Cobleskill about the cement mines in Ulster county is known as the "middle limestone ledge" and separates the Rondout, or "gray cement," from the underlying Salina waterlime locally known in Ulster county as the "black cement."

In the quarries and mines at Rondout the Cobleskill is represented by a thin layer of limestone 7 inches thick. This layer, separating the Rondout from the Salina, weathers to a gray color and is characterized by Rhynchonella ? lamellata Hall and a species of Leperditia. Southwestward from Rondout the Cobleskill thickens rapidly and at Whiteport it is 10 feet, at Binnewater 12 feet and at Rosendale 15 feet. The Cobleskill also thickens northward from Rondout, and at East Kingston it is found to have a thickness of 10 feet. The Cobleskill was also observed near Glasco, where some specimens of Proetus sp. undet. were collected. It also is seen in the vicinity of West Camp and northward toward Catskill.

In the Rosendale-Whiteport cement region Darton[1] has referred to the Cobleskill, or "middle limestone ledge," as follows:

There are two cement beds in the Rosendale-Whiteport region, and at Rosendale the lower bed, or "dark cement," averages about 21 feet in thickness, and the upper bed, or "light cement," 11 feet, with 14-15 feet of waterlimestones intervening.

In the cement region south of Whiteport there are two cement beds, the upper, or "white cement," having a thickness of 12 feet and the lower, or "gray (= black or dark) cement," 18 feet with 17-20 feet of waterlime beds between them.

The Cobleskill limestone in the Rosendale-Whiteport region contains an immense number of corals and other species characteristic of this formation in Schoharie county; but Darton did not give any account of its "coralline" character in this section. As will appear later, the Cobleskill in the vicinity of Rondout seems to have been included by Darton with the Manlius or Tentaculite limestone.

The Salina waterlime, or "black cement," is best developed at Rosendale, where it has a thickness of 22 feet, at Binnewater it

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[1] N. Y. State Mus. 47th An. Rep't. 1894. p. 528, 531.

is 15 feet and at Rondout 10 feet. It can also be seen at East Kingston, where it has a thickness of 10 feet. This bed can also be observed at Glasco and West Camp, at both of which it underlies the Cobleskill.

Below the Salina waterlime, or "dark cement," is found the "Coralline" of Hall and other authors. This limestone contains a fauna which is a mixture of Niagara and Cobleskill forms, and is indicative of the Salina age of this limestone. Over a portion of Ulster county this "Coralline" limestone occupies a position between what is usually considered the Clinton formation[1] and the Salina waterlime. In this sense this "Coralline" limestone has the stratigraphic position of the Niagara, but, as the waterlime, in age, appears to represent only the upper portion of the Salina and is transitional from the limestone below, it appears best to consider this "Coralline" of Salina age. In this paper this limestone is designated as the Wilbur limestone, since it was near Wilbur in Ulster county that Mather[2] in 1843 gave us the following interesting section, of which the basal member is the Wilbur limestone.

		Feet
1	Fossiliferous limestone like the "middle limestone of Becraft's mountain"	60
2	Fossiliferous limestone, different from the above and containing hornstone	50
3	Compact dark gray limestone (contains encrinal spines and Pentamerus)	34
4	Clouded striped limestone	20
5	*Cement rock* (gray)	2
6	Compact black limestone	1
7	Cement rock (gray), four strata	12
8	Black "coralline" limestone (various Radiaria; Cyathophylla, Catenipora, etc.) [=Cobleskill limestone]	8
9	Cement rock (gray to black) [= Salina waterlime]	8
10	Limestone, dark colored, impure and fossiliferous [= Wilbur limestone]	8
	Thickness of limestones and cements	203
11	Hudson slates and grits, thickness unknown	

[1] Though in eastern New York the terms Clinton and Medina have been retained, it is becoming increasingly evident that they are of Salina age.
[2] Geol. N. Y. 1st Dist. 1843. p. 331.

From Rondout southwestward through Wilbur, the Wilbur limestone is exposed at a number of points and rests unconformably on the Lower Siluric (= Normanskill ?) shales. Still farther soutwestward along Rondout creek the Wilbur limestone is seen resting on the Clinton quartzite, but directly west, as at Whiteport and Binnewater, the Wilbur limestone is lacking, and the cement bed rests directly on the Clinton quartzite. At High Falls there is a fossiliferous bed between the cement and the Clinton quartzite, and it is referred to the Wilbur limestone.

At localities where the Wilbur limestone or the Salina waterlime rests on the Clinton quartzite, there is no marked evidence of any unconformity, though the hiatus between them must have been considerable if this quartzite is to be considered as Clinton.

Passing north from Rondout, the Wilbur limestone is exposed in an old tramway which leads to the Becraft quarries. Darton[1] at this point gives the thickness of the Wilbur limestone as 5 inches. My examination of this section does not in all respects agree with Mr Darton's. In describing the section above referred to, he says:[2]

The lower limestone members are exhibited lying on the Hudson river slates in the railroad cut and some old cement openings near the turnpike. There is a 4 to 6 inch bed of impure, ferruginous limestone containing Niagara corals. On this there lie 7 feet of dark gray limestones, impure near the base and for 2 feet toward the top. Two feet above their bottom is a fossiliferous layer containing Atrypa reticularis, a very unusual occurrence in this part of the formation. This limestone is overlaid by a 10 foot bed of cement rock, of which the upper 4 feet are of poor quality. Next above is a heavy mass of fine grained, dark colored, brecciated limestone, filled with a great variety of corals representing the Stromatopora layer of the Tentaculite (= Manlius) series. It has here the very remarkable thickness of 10 feet with only a few thin beds of typical Tentaculite members above.

As the result of my examination of this section, I have concluded that the limestone beds containing Atrypa reticularis should be included with the Wilbur limestone, which

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[1] N. Y. State Mus. 47th An. Rep't. 1894. p.501.
[2] N. Y. State Mus. 47th An. Rep't 1894. p.511–12.

gives it about the same thickness that it has at Rondout. The 10 foot bed of cement rock above is the Salina waterlime, while the dark colored rock containing corals represents the Cobleskill. Regarding this "Stromatopora layer" as Manlius, it would allow but 10 feet between the Wilbur limestone and the Manlius or what amounts to the same, 10 feet for the combined thickness of the Salina waterlime, the Cobleskill limestone and the Rondout waterlime.

The interpretation of this section as given by Darton seems to have had much to do with his ascribing certain features to the Manlius or "Tentaculite" limestone which in reality do not exist, and, since his paper is one that is often quoted, it may not be altogether out of place to call attention to this matter. In describing the Manlius limestone in Ulster county, Darton[1] says: "There is included at or near its base, notably in the quarries near Rondout, a dark gray, impure limestone containing many corals and representing the Stromatopora horizon." This bed is unquestionably the Cobleskill, the real Stromatopora horizon being much higher. Its position is indicated in the section at Rondout. Again, in his description of the Manlius in Albany county, he says:[2] "Toward the base of the series there is usually a more massive bed containing Stromatopora, but the member is not conspicuous in Albany county in its typical development." It is very evident that Hall did not know what Darton meant by the Stromatopora bed above alluded to, for, following the last quotation, Hall adds as a correction the following footnote:

This Stromatopora bed is excellently exposed on the Albany and Schoharie plank road beyond Altamont; also about 2 miles west of the road from Albany to Clarksville on the land of Mr Merkel on the same road 2 miles northeast of Clarksville . . . Most of these exposures show that the bed lies but a few feet below the Pentamerus [=Coeymans] limestone.

The Stromatopora bed as thus located by Hall was also noticed by Darton, but the locality is not given in his description; he says:

In the upper members there is a thin subbedding, indicated by a ribboning of alternating lighter and darker tints, constituting

[1] N. Y. State Mus. 47th An. Rep't. 1894. p.449.
[2] N. Y. State Mus. 47th An. Rep't. 1894. p.441.

the "Ribbon limestone" of some writers. Just below this ribboned series there is usually a thin bed of Stromatopora which characterizes this horizon.

This is the true Stromatopora bed of the Manlius, and it appears to characterize this limestone throughout its extent in New York and always in the position as above given.

Northward from East Kingston the Wilbur limestone is mostly obscured. There is an exposure near Glasco, but from this point it is absent till West Camp is reached, where it is exposed in both limbs of a syncline which extends from West Camp to Catskill. The Wilbur limestone about West Camp is 3 feet thick, and outside of its corals Leptaena rhomboidalis Wilck. is the abundant fossil. Atrypa reticularis Linn. also occurs, but not so abundantly. The presence of the Wilbur beds far north of West Camp has not been established. There are corals at the base of the Rondout and on the Lower Siluric shales at Catskill, but they are considered as belonging to the Cobleskill.

Results somewhat similar to those which I have obtained relative to the stratigraphic relations of the cement beds at Rondout have been already expressed by the Hon. J. G. Lindsley[1] in a paper read before the Poughkeepsie Society of Natural Science in 1879. While the correlation of the cement beds at Rondout as given by Lindsley, differs essentially from that of the writer, it serves to show nevertheless that the cement beds at Rondout have before been considered as belonging to different ages, and this opinion is expressed by one who, as superintendent of the Newark Lime & Cement Co., was familiar with the section, and to whom the proper relations of the cement beds were of prime importance. The following quotation from the paper referred to above will clearly express the views held by Lindsley. In referring to quarries at Rondout, he says:

> In these quarries we find lying directly upon the slates, [=L. Siluric] two layers of coralline [=Wilbur] limestone, the whole thickness of which varies from 6 feet to nearly 8 feet.
>
> This coralline limestone is admitted by all geologists of the present time to belong to the Niagara epoch, being the small beginning of those rocks here at the east, which, increasing in thickness, assume such proportions in the western part of the State.

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[1] *See* Poughkeepsie Soc. Nat. Sci. Proc. 1879. p.44-48.

Let us now inquire if these are the only rocks at this place which belong to this epoch.

We find lying between this coralline limestone and the tentaculite limestone of the Lower Helderberg some 40 feet of rock, of which most of the layers are used in the manufacture of cement, and this feature holds good for some distance to the north and south of this point, but under quite different circumstances. At the Vlight Berg we have several courses or layers lying together, to the thickness of about 22 feet, all of which is used in the manufacture of cement, hitherto known as waterlime, and quite generally regarded as wholly belonging to the Waterlime group. The upper layers of this waterlime are of a light grayish drab in color, but those that lie directly upon the coralline limestone are nearly black. There is about the same thickness of each, and they are known by the quarrymen respectively as the light and dark cement. Now as we go either north or south, even no further than the Steep Rocks on the one hand, or Wilbur on the other, we find these light and dark cements separated; and between them is found another layer of limestone [= Cobleskill], so that instead of one thickness of cement rock of 22 feet, we have two of 12 or 15 feet each, the light colored lying above, and the dark below this intermediate layer. This last represents the general features and disposition of the rocks in nearly, if not quite all of the cement quarries in Ulster county, except those of the Vlight Berg. Dr S. T. Barrett, of Port Jervis, has made the rocks of the lower Helderberg and those immediately below them, in his vicinity, a special study for some time, and he is inclined to the opinion that our black cement rock and the overlying coralline limestone, where that occurs, belong to the Niagara epoch, and I am led to the same view for the following reasons. The dark cement rock quite often presents a coralline structure, and the fossil molluscae and trilobites found embedded are such as seem to belong to the Niagara epoch. I have one of the latter which is nearly perfect, although it has been subjected to the burning process of the kilns. It answers every requisite of the Calymmene niagarensis, except as to size, it being somewhat larger than other specimens I have seen. The coralline layers above the dark cement, where they prevail, have many specimens of Halysites, or chain coral, embedded in them, which Dr Hall says are not found above the Niagara. If this conclusion is correct regarding the proper classification of these rocks, we have existing at the Vlight Berg a state of stratification quite peculiar, in that the layers belonging to the Niagara epoch that are suitable for the manufacture of cement directly underlie the layers of the waterlime, so extensively used for the same purpose, and which so generally form the base of the Helderberg group.

The views as above expressed by Lindsley seem not to have been much in accord with those of contemporaneous writers, and, in fact, we are not altogether certain that Lindsley himself always retained the conclusions given in his paper. Dale,[1] in a paper written at about the same time, refers to the upper Niagara beds of Lindsley in a manner which expresses doubt of their actual existence. Prof. W. M. Davis[2] in a later paper intended, in part at least, to serve as a supplement to the earlier ones of Lindsley and Dale, entirely ignores the section at Rondout as construed by Lindsley and gives 70 feet as the combined thickness of the water-lime (= Salina + Cobleskill + Rondout) and the Tentaculite (= Manlius) limestone. The Coralline (= Wilbur) limestone is given a thickness of 6 to 8 feet. This measurement as well as the preceding one is credited to Lindsley.

Fauna of the Wilbur limestone

The Wilbur limestone is fossiliferous wherever it has been examined. One of the best localities for the collection of its fossils is in the old mines at Rondout. The limestone contains fossils throughout its whole thickness, but collecting is best near the top, where the overlying cement has been removed for a time sufficient to allow the rock to weather. This requires but a comparatively short period. The following species have been collected from the Wilbur limestone, and it is quite probable that the list will be increased when more extensive collections shall have been made at other localities.

1 Favosites *cf.* niagarensis *Hall*
2 Halysites catenulatus *Linn.*
3 Enterolasma caliculus *Hall*
4 Bryozoan *sp. undet.*
5 Atrypa reticularis *Linn.*
6 Camarotoechia neglecta *Hall*
7 Leptaena rhomboidalis *Wilck.*
8 Orthis hybrida *Sow.*
9 Orthothetes interstriatus *Hall*
10 Orbiculoidea *cf.* tenuilamellata *Hall*

[1] Am. Jour. Sci. 1879. 18:294.
[2] Am. Jour. Sci. 1883. 26:389–95.

11 Rhynchonella ? lamellata *Hall*
12 Pholidops ovalis *Hall*
13 Stropheodonta bipartita *Hall*
14 S. textilis *Hall*
15 Whitfieldella *cf.* nitida *Hall*
16 Conocardium *sp. undet.*
17 Pterinea *cf.* emacerata *Conrad*
18 Murchisonia *sp.*
19 Spirorbis *sp.*
20 Tentaculites *sp. undet.*
21 Beyrichia *sp.*
22 Dalmanites *sp.*
23 Proetus *sp. undet.*
24 Calymmene camerata *Conrad*
25 C. niagarensis *Hall*

Distribution of the fauna of the Wilbur limestone

	Niagara	Cobleskill, Schoharie co.
Favosites *cf.* niagarensis	×	×
Halysites catenulatus	×	×
Enterolasma caliculus	×	×
Rhynchonella ? lamellata		×
Atrypa reticularis	×	×
Camarotoechia neglecta	×	×
Leptaena rhomboidalis	×	×
Orthis hybrida	×	
Orthothetes interstriatus		×
Orbiculoidea *cf.* tenuilamellata	×	
Pholidops ovalis	×	
Stropheodonta bipartita		×
S. textilis		×
Whitfieldella *cf.* nitida	×	
Pterinea *cf.* emacerata	×	
Calymmene camerata		×
C. niagarensis	×	×

An examination of the above faunal list shows at once that we have here an assemblage of species that strongly indicates that the Wilbur limestone is intermediate between the Niagara and the Cobleskill or, as already indicated, it is of Salina age.

In Ulster county there is a space above the Wilbur limestone represented by the lower cement bed that, with the exception of Leperditia, is almost nonfossiliferous, but, when the Cobleskill is reached, we have again, in part, the Wilbur limestone fauna, but with a less proportion of Niagara species and with an increase of new forms that have not been observed in any formation below the Cobleskill.

In the 42 feet of shales and limestones below the Cobleskill of the Nearpass section in New Jersey there occurs a fauna which like that of the Wilbur limestone is Niagaran in character. In the latter section however the cement bed, so conspicuous below the Cobleskill, in Ulster county, is lacking, and the formation is more or less fossiliferous throughout. Some of the layers in the New Jersey section are crowded with Leperditia strongly suggesting brackish water conditions, but to a much less extent than in Ulster county.

The fauna of the Nearpass section has been studied with some detail by Weller,[1] and he was able to identify with more or less certainty 31 species that for the most part are well known Niagara species. Some of the identifications as thus made by Weller, presumably those of Niagara species, have been questioned by Ulrich and Schuchert;[2] but, judging from the fact that we do have Niagara species below the Cobleskill in Ulster county and relying on the previous work of Weller, it would not be unsafe, I think, to assume that there is below the Cobleskill in the Nearpass section, as in Ulster county, a fauna with unmistakable Niagara elements.

One of the chief differences between the section in Ulster county and the Nearpass section is the development in the former of an extensive cement bed which is entirely lacking in the latter, but is represented by shales and limestones. In the Ulster county section the marine conditions during which the fauna of the Wilbur limestone flourished seem to have been followed by a period of nonmarine or brackish water conditions, during which the overlying cement bed was formed. This change in conditions of sedimentation caused an almost entire destruction of the fauna,

[1] N. J. State Geologist. An. Rep't. 1899. p.7–20.
[2] N. Y. State Paleontologist. An. Rep't. 1901. p.650.

and in part accounts for the great abundance of fossils found at the top of the Wilbur limestone, where it grades into the cement rock above. In a like manner immense numbers of ostracods are found at the top of the cement at the juncture with the Cobleskill limestone. At the close of the Cobleskill there is an almost complete annihilation of the fauna. The nonmarine conditions of the Rondout were much more widespread in their influences than those during which the lower cement bed was formed, and throughout the extent of the Rondout in New York but few of the Cobleskill species pass upward into this formation. In some of the shaly layers at the top of the Cobleskill in Ulster county very many remains of trilobites and other fossils have been found, and somewhat similar conditions have been observed in Schoharie county.

In the Nearpass section the conditions so affecting the faunas farther north are not so apparent, and the rock is of a more calcareous nature throughout, and some of the species found in the lower part pass directly upward into the Cobleskill limestone.

The age given to the formation below the Cobleskill in the Nearpass section as determined by Weller was the same as the Niagara. His determination, however, was made when the Cobleskill was supposed to represent the eastern extension of the Niagara. Still he showed that the Cobleskill can represent only the upper portion of the Niagara, and that it is transitional from the underlying limestone and shales. As we now know that the Cobleskill is just above the Salina, the fossiliferous formation just below the 6 foot bed of Cobleskill in the Nearpass section will be considered of Salina age. The Bossardville limestone lying below these fossiliferous beds in the Nearpass section, is also considered of Salina age.

The Nearpass section as above construed, as well as the section in Ulster county, does not include any formation of Niagara age. The absence of the Niagara from these sections may in part be accounted for as follows. Beginning with Oneida sedimentation [fig. 4] we have each of the successive deposits overlapping the next older till the Niagara is reached. This series of overlaps is observed of the deposits in eastern New York laid down in the

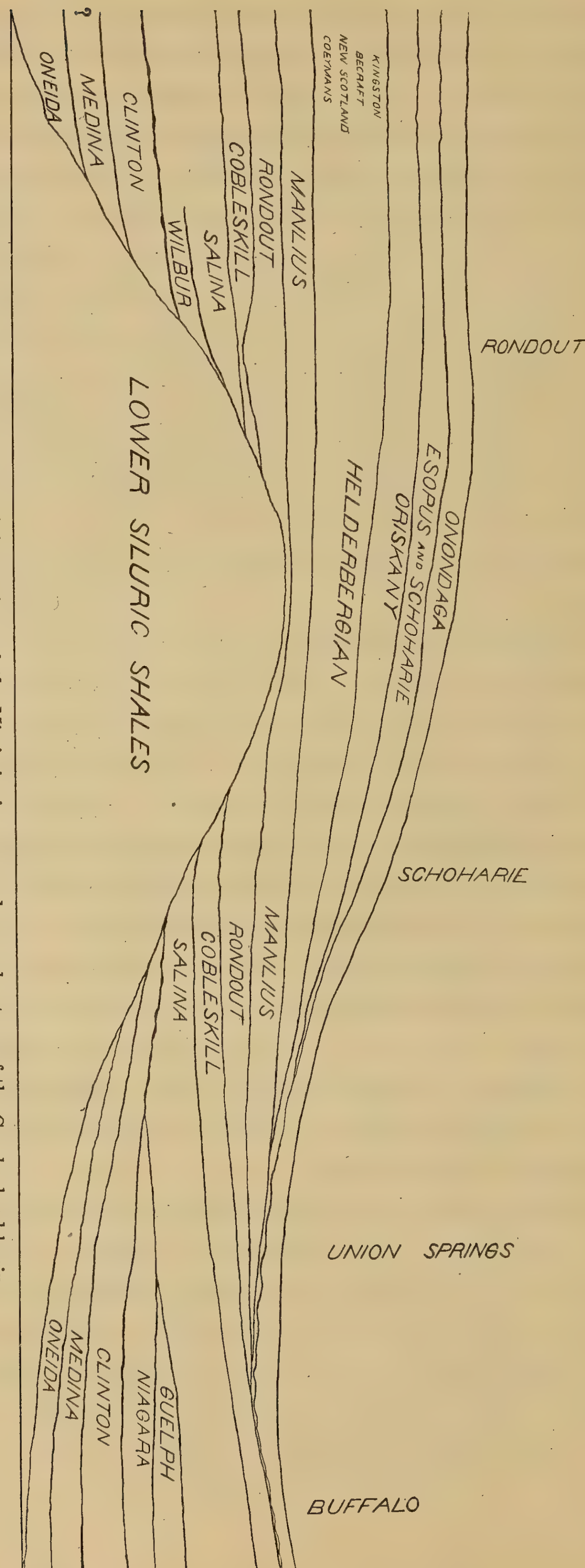

Fig. 4 Diagram showing overlaps and succession of formations of the Mississippian sea and an early stage of the Cumberland basin

Cumberland basin[1] as well as in central New York laid down in the Mississippian sea.[2] The overlapping of these deposits was caused by the gradual subsidence of a mountain barrier which separated the two basins, and which as subsidence took place caused the overlapping edges of the successive deposits in these two basins gradually to approach each other, the thinned edge of each resting on the Lower Siluric shales. At the close of the Clinton there was a reelevation of the barrier, and the Niagara deposits do not overlap the Clinton formation and rest on the Lower Siluric shales, but in central New York the eastern extension of the Niagara is found resting on the Clinton. The effect of this uplift on the limits of the Niagara deposits in the Cumberland basin is not so apparent, but none seem to have been deposited in New York.

From late Niagara time subsidence again took place, and the Salina deposits of the Mississippian sea in New York spread east over the Niagara and Clinton formations, and the thinned edge rests on the Lower Siluric shales. A similar condition of overlap is found in the deposits of the Salina age in the Cumberland basin. In the region of the Helderberg the Salina deposits of the Mississippian sea are separated from those of the Cumberland basin by quite an interval, but in southeastern New York, where the barrier was lower, they must have been very close together, and the last deposits may have mingled and a few Eurypterus passed from the Salina sea into the Cumberland basin.

With the clearing of the water brought about by the subsidence of the barrier, the Salina stage was brought to a close, and we have the Atlantic waters spreading over the late Salina sea. The spreading of the Atlantic waters over this area brought with them an Atlantic fauna. This invasion is known as the Helderbergian, or it may be properly designated the Cobleskill invasion, since it was during Cobleskill time that we have the first invasion of an Atlantic fauna into the interior following the Salina age. This invasion of the Atlantic waters explains in part the derivation of the fauna of the Cobleskill limestone as found in Schoharie county.

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[1] N. Y. State Paleontologist. An. Rep't. 1901. p.638.
[2] Am. Ass'n. Adv. Sci. Proc. 1894. 42 : 129-69.

Guelph element in the fauna of the Cobleskill limestone

Mingled with the species of the Cobleskill derived from Atlantic waters, there are found in Schoharie county and westward a number of gastropods and cephalopods with some lamellibranchs, all of which in the eastern extension of the Cobleskill are conspicuously lacking. An analysis of this element in the Cobleskill fauna shows that a number of the species are identical with Guelph species of New York and the West. Among these forms are found such Guelph species as Orthoceras trusitum Clarke & Ruedemann, Kionoceras darwini Billings and Ilionia galtensis Whiteaves and other species which appear in the foregoing lists. Species common to the Niagara and the Guelph and not observed in the Cobleskill of eastern New York occur in Schoharie county with the true Guelph species. There are also Niagara species in the Cobleskill found in the Niagara of the West, but which do not occur in the Niagara of New York.

The presence of Guelph species in the Cobleskill is accounted for as follows. At the close of the Niagara age there was an increase in the salinity of the water, which was the first step toward bringing about the conditions of the Salina sea. During this period following the Niagara, the Guelph fauna of New York flourished, but finally retreated as the sea became more saline. Again at the close of the Salina age, when in western and central New York nearly normal marine conditions had been established, the Guelph fauna returned and met the invading fauna of the Atlantic. The mingling of these two faunas shows that during Cobleskill time the waters of the Atlantic and the Mississippian sea were in communication.

In the conclusion which I have reached relative to the mingling of these waters I differ from Ulrich & Schuchert,[1] who state that, though the barrier to the east was crossed, a younger fold "still prevented the Atlantic from joining the Mississippian sea throughout the time from Medina well into the Oriskany."

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[1] N. Y. State Paleontologist. An. Rep't 1901. 1902. p.662.

Rondout formation

The mingling of the Atlantic waters with those of the Mississippian sea was of but short duration, and the Cobleskill was brought to a close by the formation of a barrier in western New York. This barrier as it grew caused a retrogression of the succeeding deposits lasting into Devonic time and effectually separated the waters of the Atlantic from the Mississippian sea till late Oriskany time, when some of the Oriskany sand was deposited in the crevices forming dikes and on the eroded surface of the Cobleskill.

With the elevation of the Cobleskill in western New York, the true marine conditions under which the Cobleskill fauna flourished were also brought to a close, and in New York there was again formed a lagoon or bay in which the Rondout sediments were deposited. This bay was similar in some respects to the early Salina sea, but was diametrically opposite in that it formed an arm of the Atlantic instead of the Mississippian sea. The conditions following the close of the Cobleskill were such that but few of the Cobleskill species pass up into the Rondout. That the Rondout was, unlike the Cobleskill, a nonmarine formation is shown by the return of the Eurypterus fauna, though much reduced in force. At Seneca Falls Eurypterus have been found in the Rondout but 2 feet below the Oriskany sandstone. They have also been observed in several localities about Union Springs and eastward. The writer has found Eurypterus remipes, in place near Cherry Valley at a horizon which may possibly prove to be the Rondout; and, till the exact horizon is determined, this find is chiefly interesting in that it is the most eastern locality in New York from which Eurypterus has been obtained.

In eastern New York and the Helderberg the conditions favorable for the existence of Eurypterus seem to have been lacking, at least none have been found indicating that these localities were in more direct communication with the sea. The fauna found at the base of the Rondout in the Helderberg sections is made up of species which continued their existence from the Cobleskill, and which do not pass upward into the Manlius limestone. In central New York there is a relation between the

faunas of the Rondout and the Manlius, and this relation is expressed chiefly by the passage of Eurypterus up into the Manlius limestone.

Hall[1] early called attention to the finding of "a specimen containing a part of the head of a Eurypterus and several impressions of a spirifer peculiar to the tentaculite limestone. The character of the rock is intermediate in color, texture and composition, between the ordinary drab colored layers of the Onondaga salt group, and those of the tentaculite limestone." It is possible that the above specimen may have been obtained from the Rondout. Dr Clarke, however, has recently informed me that he has found Eurypterus in the blue layers of the Manlius limestone in Herkimer county. In Onondaga county, above the blue layers containing the typical Manlius limestone fauna there are two layers of "Waterlime" from which the original "waterlime of Manlius" takes its name. From the upper layer of this waterlime Luther[2] obtained a segment of a Eurypterus, showing that these interesting creatures continued their existence through all of late Siluric time, and that in this section at least there was an alternation in the character of the sediments and, as suggested by the fauna found in them, a considerable variation in the degree of the purity of the waters in which the sediments were deposited.

Culmination and decline of the Salina sea

The occurrence of Guelph and Niagara species in the Cobleskill at the close of the Salina is very suggestive. The limits of the Salina deposits as now known are marked faunally by lower and upper Eurypterus beds, signifying that the period opened and closed under similar physical conditions. If, however, we start at the close of the Niagara period, we find the first indication of increasing salinity, and with this change came the Guelph[3] fauna. With the ever increasing salinity of the waters the Guelph fauna

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[1] Palaeontology of New York. 1852. 2:339.

[2] N. Y. State Geologist. 15th An. Rep't. 1898. p.268.

[3] This fauna, together with the environments under which it lived, has recently been studied by Clarke and Ruedemann, and is described in memoir 5 of the New York State Museum.

retreats, and next in the black Pittsford[1] shale at the base of the Salina there occur Eurypteri, and with them constantly asso-

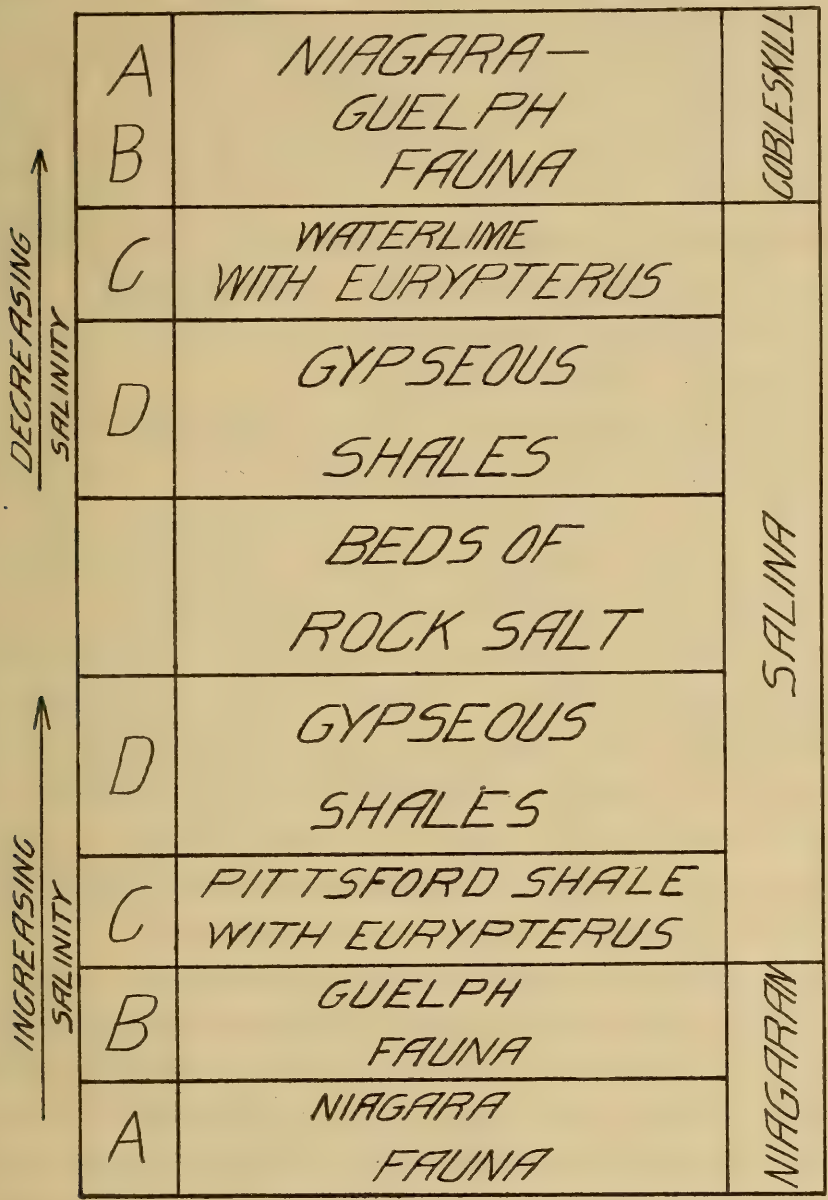

Fig. 5 Cycle of events showing the culmination and decline of the Salina sea

ciated a species of Lingula. With the retreat of this fauna we find, as physical changes went on, deposits of gypseous shales

[1] The Pittsford shale, which is exposed in the vicinity of Pittsford, Monroe co., is very dark and fragile, checking rapidly in drying. Intercalated in this shale are thin layers of gray dolomite carrying species similar to *Leperditia scalaris* Jones and *Pterinea subplana* Hall. *Leperditia scalaris* is a characteristic species of the Cobleskill in Erie co., while *P. subplana* appears to be represented in the Cobleskill of the Schoharie section. The eurypterid and pterygotid species of the Pittsford shale are described by Mr C. J. Sarle in the annual report of the state paleontologist, of which this paper forms a part.

and later the salt beds. The deposition of these great beds of rock salt marks the turning point in this cycle, at which time the Salina sea contained very little if any water at all. With the increasing depth of the sea, beds of gypsum were again deposited, but never again were the conditions favorable for the deposition of extensive beds of rock salt. Following the gypsum beds, we have the Salina waterlime with its splendid Eurypterus fauna, and associated with the Eurypterus is a species of Lingula similar to the one at the base of the Salina. Above the Eurypterus beds we have the Cobleskill limestone, and here again we have representatives of the Niagara-Guelph fauna.

Era or system	Period or group	Age or stage
[1] Ontaric or Siluric	Cayugan (Neontaric)	Manlius limestone Rondout waterlime Cobleskill limestone Salina beds Wilbur limestone, (Pittsford shale, local facies)
	Niagaran (Mesontaric)	Guelph dolomite Lockport limestone Rochester shale Clinton beds
	Oswegan (Paleontaric)	Medina sandstone Oneida conglomerate Shawangunk grit

Upper Siluric sections in Onondaga county

The upper limit of the waterlime group of Vanuxem, in the eastern part of the third district was marked by the Coeymans limestone. At the type locality of the Manlius limestone in Onondaga county, where the Coeymans limestone together with the other members of the Helderbergian formation were supposed to be absent (not being recognized west of Madison county), the Waterlime group included all the strata up to the Oriskany sandstone.

In the townships of Manlius and Dewitt, Onondaga county, the thickness of the strata from the gypsum beds of the Salina to the Oriskany sandstone is 190 feet. The lower portion

[1] Ontaric or Siluric of the New York series as modified from *Science*, Dec. 15, 1899.

of the section can be best studied in the vicinity of the Heard gypsum quarry 1 mile south of Lyndon in the town of Dewitt. The middle portion is best shown at Brown's falls on the west branch of Limestone creek, 1½ miles southwest of the village of Manlius, while the upper portions are made accessible by the natural outcrops and the extensive quarries in the hill just east of Manlius.

Section at the Heard gypsum quarry

Salina formation. North from the quarry there is exposed in the road and in the fields a dark porous limestone. In some of the thinnest layers Leperditia cf. scalaris is very abundant, while a small species of Whitfieldella is very common in the other portions of the rock. This limestone was formerly burnt for lime and its horizon is about 40 feet below the gypsum exposed in the quarry. The interval between this outcrop and the base of the gypsum quarry does not show any outcrop of the limestone. The gypsum including numerous intercalations of shale, is 65 feet thick and is overlain by 10 feet of olive-green shales which are quite soft, and often they lose their regular structure and become complicated, due largely to dissolving out of gypsum and to changes which have taken place in the underlying mass. Above these soft shales there are 6 feet of Salina waterlime. The appearance of the rock is similar to the Salina waterlime of Herkimer county. Fragments of Eurypterus are frequently seen but the Lingula found at the same horizon farther west has not been observed. A small quantity of Salina waterlime taken out in the process of quarrying gypsum is now burned for cement, but it has never formed an important factor in the cement industry of Onondaga county.

Cobleskill limestone. The Cobleskill limestone directly succeeds the Salina waterlime. In this section the basal portion for 4 feet possesses the usual features of the Cobleskill of the eastern sections and is characterized by such fossils as Spirifer crispus var. corallinensis, Whitfieldella nucleolata, Chonetes jerseyensis and Stropheodonta bipartita. The upper portion is transitional into the Rondout waterlime, from which it is not readily distinguishable.

Rondout waterlime. Only the basal portion of the Rondout is shown in this section. The rock here is brecciated and filled with cavities, some of which are quite large. Many of the smaller cavities are due to the dissolving out of the coral Cyathophyllum hydraulicum Simpson. In appearance this rock is similar to the "bullhead" rock of Erie county. The Rondout is burned to a small extent for cement, and then only when it is mixed with the cement rock of the upper horizons.

The section as above given agrees essentially with one near Jamesville, published by Vanuxem.[1] Number 5 of his section is the Salina waterlime and according to his statement this was the only locality in the third district south of the Erie canal where cement was made from the rock of these lower horizons [p. 110]. Number 6 includes what is now recognized as the Cobleskill limestone and the lower portion of the Rondout waterlime. The cyathophyllum mentioned by Vanuxem [p. 110] is unquestionably the one that is now identified as Cyathophyllum hydraulicum Simpson. The section given by Vanuxem is described under the *third* or *gypseous* deposit of the Onondaga salt group and is important in showing that in the type locality of the original waterlime group in Onondaga county not only Salina waterlime, but also the formations now known as the Cobleskill limestone and the Rondout waterlime, were included in the Onondaga salt group and not in the Waterlime group as has been generally supposed.

Section at Brown's falls

Cobleskill limestone. On the west branch of Limestone creek 1½ miles southwest from Manlius village the Cobleskill limestone is exposed in the bed and banks of the creek 200 yards below the foot of the falls. The Cobleskill is here a compact limestone. The strata below the Cobleskill are only obscurely shown.

Rondout waterlime. The basal portion of the Rondout is filled with cavities, and is similar to the lower portion as seen in

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[1] Geol. N. Y. 3d Dist. 1842. p. 105.

the Heard quarry. The upper portion of the Rondout is composed of thin layers of impure limestones. The total thickness of the Rondout as determined at this section is 45 feet.

Manlius formation. The lower portion of the Manlius is similar in appearance to the upper portion of the Rondout and gradually changes to the characteristic blue layers. The blue layers carry the typical Manlius fauna. In some of the layers fossils are exceedingly abundant, while in others they are rare. Some slabs contain an immense number of Spirifer vanuxemi and others contain equally large numbers of Leperditia alta. Tentaculites gyracanthus, so plentiful in the Helderberg section, is not found abundantly at Manlius. The Stromatopora bed of the Manlius occurs at the top of these blue layers just below the lower cement bed. In the eastern sections the Stromatopora bed is near the top of the Manlius not far below the Coeymans limestone. The thickness of the Manlius limestone up to the cement bed is 65 feet.

The cement bed which follows the Stromatopora bed is 4 feet thick. No fossils have been observed in this layer. Above this cement bed is a layer of blue limestone 4 feet thick. Spirifer vanuxemi and Leperditia alta were obtained from this bed. The limestone is followed by another layer of cement 4 feet thick. Mr Luther records the finding of a segment of a Eurypterus from this upper cement bed in the quarry at Split Rock, south from Syracuse. The section above the cement beds can be observed in this vicinity but not so advantageously as in the hill east of Manlius.

Section in the hill east of Manlius village

The lower part of the Manlius limestone is not well exposed. It can be seen however at the cut of the Chenango branch of the West Shore Railroad northwest from the station. In this cut there is a brecciated layer of limestone 1 foot thick. The rock in this cut and in the outcrops in the fields above is very fossiliferous. The two layers of cement are well exposed in this hill where they are extensively quarried for cement. Above the upper cement bed there is an irregular layer of limestone 14 feet thick. In lithologic features it closely resembles the

Manlius. It is but sparingly fossiliferous and appears to be transitional into the Helderbergian to which formation it is provisionally referred. This blue limestone layer is followed by the Stromatopora bed 12 feet thick. The upper portion is very much broken by the formation of deep vertical fissures, similar to those seen in the Coeymans limestone. This Stromatopora layer is referred to by Vanuxem [*loc. cit.* p. 110] where he says: "One of the layers, usually from four to five feet in thickness, is traversed by oblique cracks in at least three directions, breaking the mass into irregular parts or fragments; this layer is very fine grained." Besides Stromatopora found in this layer, corals of the genus Favosites are quite abundant. Spirifer cyclopterus is also frequently found.

The Stromatopora bed is followed by 14 feet of massive blue limestone locally known as the "upper blue beds." Fossils other than Leperditia are rare in these beds. Following these "upper blue beds" and directly below the Oriskany sandstone there is a massive gray limestone 6 feet thick in which some species of fossils are very abundant. This gray limestone appears not to be present at all localities and where absent the Oriskany sandstone follows directly the "upper blue beds." The following species were obtained within 8 feet of the Oriskany sandstone.

1 Leptaena rhomboidalis *Wilckens*
2 Orbiculoidea *cf.* discus *Hall*
3 Spirifer cyclopterus *Hall*
4 Stropheodonta becki *Hall*
5 Trematospira formosa *Hall*
6 Meristella *cf.* laevis *Vanuxem*
7 Conocardium *sp. undet.*
8 Pterinea communis *Hall*
9 Tentaculites elongatus *Hall*
10 Leperditia *sp. undet.*

General section at Manlius, Onondaga county

		Feet
1	Oriskany. Fossiliferous sandstone, 6 inches to 2 feet thick	.
2	Helderbergian. Gray, compact fossiliferous limestone	6
3	Helderbergian. Blue limestone beds	14
4	Helderbergian. Stromatopora beds, upper portion much broken	12
5	Helderbergian? Blue limestone, fossils rare	14
6	Manlius. Upper waterlime bed. Eurypterus in this layer at Split Rock	4
7	Manlius. Blue limestone with Spirifer vanuxemi and Leperditia alta	4
8	Manlius. Lower waterlime bed	4
9	Manlius. Stromatopora bed at top. Blue layers below containing typical Manlius fauna	65
10	Rondout. Upper portion, light weathering impure limestone; lower portion, a cement rock with cavities	45
11	Cobleskill. Fossiliferous limestone gradually grading into the Rondout	6
12	Salina. Waterlime with Eurypterus	6
13	Salina. Soft, greenish shales	10
14	Salina. Gypsum beds, with intercalations of shale	65
		255

SUPPLEMENTARY NOTE

While the foregoing pages have been passing through the press Mr Charles Schuchert[1] has published a paper "On the Manlius Formation of New York." The results obtained by Mr Schuchert and myself have been largely based on the same sections, though we differ considerably in our stratigraphic and faunal interpretations of them. As I have had recently an opportunity to examine the section about Litchfield, Herkimer co. it seems to me best to note in what respects we have differed in our sections and hence why we differ so widely in our results, specially in regard to the grouping of the rocks under consideration, a difference which to a large degree would have been avoided, were we more in accord in our stratigraphic and faunal determinations.

[1] American Geologist. March 1903. p.160–78.

Section near Port Jervis (Nearpass quarry section)

For reasons which are more fully stated hereafter Mr Schuchert proposed to include under the group term Manlius, the Manlius or Tentaculite limestone, the Rondout waterlime and the Cobleskill limestone as developed in the counties of Schoharie and Herkimer. In the section about Port Jervis it is very evident that these limits have been greatly exceeded and that he has included with the Manlius, strata which contain a fauna that is unquestionably older than the fauna of the Cobleskill as developed in its typical sections. Below the Cobleskill in the Nearpass section there are 42 feet of shales and limestones. "The diagnostic fossil of the lower half is Chonetes jerseyensis, otherwise the fauna is that of the Cobleskill member minus its corals" [p. 174]. It will thus be seen that not a single Niagaran species is recognized in this section since according to Mr Schuchert the Cobleskill contains no Niagaran species. This however is not in agreement with determinations made by Barrett, Weller and Whitfield, who have recognized Niagaran species therein. The Bossardville limestone at the base of the formation is correlated by Mr Schuchert with the Salina.

Section at Rondout

The Rondout formation as originally defined was intended to apply to the upper beds of the Salina characterized by an abundance of Eurypterus. Since it has been shown that at the type locality of the Rondout, the Wilbur limestone (= Coralline of Hall) is not the equivalent of the Cobleskill but belongs to an earlier age and stratigraphically lies below the cement bed of the Salina as well as below the Cobleskill, it follows that in its type locality the Rondout beds originally included the stratigraphic equivalent of the Eurypterus bearing waterlime of the Salina, the Cobleskill limestone and the Rondout waterlime as now restricted to that portion lying above the Cobleskill limestone. The restricted sense in which I have used the term Rondout may be the same as the intended use of this term by Mr Schuchert, but in the Rondout section he has failed to recognize the true Cobleskill, and hence his application of the term Rondout here is with its original limits and includes beds of Salina age, while in the other

sections cited by him it is restricted to the waterlime above the Cobleskill limestone. For the upper Eurypterus-bearing beds of the Salina Mr Schuchert uses the term Bertie formation which was introduced by Chapman in 1864. This formation stratigraphically is equivalent to the basal portion of the original Rondout.

Herkimer county section

In the town of Litchfield the upper Eurypterus beds of the Salina are exposed on the farm of Prof. C. F. Wheelock. Near the outcrop of the Eurypterus beds, Wheelock's creek has its origin. This creek flows north and joins Moyer creek near the point where the Oneida conglomerate outcrops. It is along Wheelock's creek that the following section was observed.

Oneida conglomerate. Basal member very coarse, resting on the Lorraine. After 5 feet of conglomerate there is an alternation of sandstone and conglomerate which finally grades into the Medina. The pebbles are found quite abundantly for 45 feet.

Medina sandstone. Above the conglomerate are about 70 feet of Medina sandstone. In his section Schuchert states that the Medina is absent. Likewise Vanuxem[1] and Hall[2] both state that the Medina is not found east of Oneida county. It should be observed, however, that Hall's statement appears to have been based on the report of Vanuxem and the latter always considered the Clinton as directly following the Oneida while the Medina was described as below the Oneida. A single quotation from Vanuxem's report [p. 75] will serve to show that he regarded the Oneida as part of the Clinton. He says "The conglomerate forms a part of the Clinton group, the next mass in order of superposition."

Clinton formation. The Clinton shales and sandstones are well exposed and have a thickness not far from 150 feet.

Niagara formation. The presence of the Niagara in this section is of special interest in showing that at one of the original localities of the Cobleskill limestone we have both the Niagara and the Cobleskill present, being separated from each other by the entire

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[1] Geol. N. Y. 3d Dist. 1842. p. 72.
[2] Palaeontology of New York. 1852. 2:4.

thickness of the Salina, thus proving by the section along Wheelock's creek the true stratigraphic position of the Cobleskill limestone.

In his section Mr Schuchert states that the Niagara is absent and that "Hall was able to find the Niagara formation as far east as Oneida county" [p. 162]. Vanuxem[1] records the presence of the Niagara in Steeles creek, Herkimer county. This outcrop is about 3 miles southeast from the section under consideration, and its presence there is also recorded by Hall.[2] The Niagara can be observed in place there on the right of the highway passing from Ilion to Cedarville. This exposure affords a favorable opportunity to study the concretionary nature of the Niagara and its contact with the Salina shales. The Niagara has not been observed east of Steeles creek. There are some sections in western Herkimer and eastern Oneida where the Niagara is covered. Hall[3] states: "Over a part of Oneida county and the western part of Herkimer, there is a space where no representative of the Niagara group has been traced continuously; not that the place where it should occur has been examined and found to be wanting, but because there are no good exposures of the strata which enable one to examine and determine satisfactorily the presence or absence of a thin bed like this one. In tracing the same line eastward however, into Herkimer county, there is a thin mass of limestone holding the same place, but more closely united perhaps with the drab limestone above, which is the thinned Onondaga-salt group." The thin mass of limestone referred to is the Cobleskill. Tracing the Niagara from Oneida county eastward should have brought Hall to the exposure of the Niagara on Steeles creek, but at a point west of Steeles creek, he records the presence of the Coralline thus showing that the position of the Cobleskill as given by Hall was due to some extent to an error in correlation in Herkimer county.

In Wheelock's creek the Niagara is thin, but the contact with the Clinton and the Salina can be favorably seen in the bed of the stream. The geodic concretions containing dolomite crystals,

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[1] Geol. N. Y. 3d Dist. 1842. p. 91.

[2] Palaeontology of New York. 1852. 2:107.

[3] Palaeontology of New York. 1852. 2:321.

readily distinguish the Niagara from the adjacent rock masses. At this particular locality the base of the Niagara is a very dark shale, possibly the eastern extension of the Rochester shale.

Salina beds. The red shales of the Salina are excellently exposed along the creek bed and highway which crosses the creek below Wheelock's farm. A considerable portion of the upper Salina is not shown, but the Eurypterus waterlimes are exposed on the Wheelock farm. The total thickness of the Salina can not be much less than 500 feet.

Cobleskill limestone. The best exposures of this limestone in the vicinity of the Wheelock farm is on the Augar and Morris farms, and in the highway ½ mile east of Wheelock's. It is also exposed 2 miles east, not far from Steeles creek on the Kolb farm. There are other outcrops of the Cobleskill southeast from Wheelock's near the Palmer cheese factory. Near the latter place the Eurypterus beds are shown in the highway and the Cobleskill outcrops just above, and for a mile frequent exposures are seen near the highway leading to Cedarville.

The thickness of the Cobleskill in Herkimer county is given by Mr Schuchert as 30 feet, but I have not been able to find any outcrops where the thickness was so great. Hall states that in Herkimer county it is "only a few feet thick" and observations made about the Kolb farm show a thickness of about 10 feet, though there are places where through the action of the "creeping" movement of the detached edge of the outcrop the thickness appears to be greater. The contact of the Cobleskill with the Rondout was advantageously observed at only one point. At the top of the Cobleskill Leperditia scalaris Jones and a large species of Beyrichia were found quite abundantly.

Rondout and the Manlius formations. The combined thickness of the Rondout and the Manlius is about 100 feet. The Rondout is of a sandy hydraulic nature with but few fossils. In the thin sandy layers Eurypterus are occasionally found. On one slab from the Rondout with Eurypterus there is found Rhynchonella ? lamellata Hall and Whitfieldella sp. The Manlius contains its usual fauna and in this section it is also characterized by many beautiful crinoids. The upper portion of

the Manlius becomes complicated with the Coeymans limestone, the faunas of these two formations either mingling or alternately recurring.

Age of the shales below the Cobleskill at Schoharie

The shales below the Cobleskill at Schoharie were designated as Clinton by Hall and now that we know that the Cobleskill is above the Salina the age of these unfossiliferous shales again comes into question. Mr Schuchert [p. 173] holds that "on the basis of the adjoining sections, the age of these olive green shales seems to be Lower Cobleskill." What appears to be the chief argument, given for the determination of the age of the shales as Lower Cobleskill is as follows [p. 176]. "In Herkimer county the Clinton is not followed by the Niagaran, but at once by the Salina. Farther east the Clinton also fails, and at Schoharie, after 19 feet of the pyritiferous shales, there follow at once the Cobleskill, the Rondout, with the Coralline fauna, the Upper Manlius, and then the Helderbergian. Here the united thickness of the Cobleskill, Rondout and Upper Manlius is 91 feet, while about Litchfield the same zones are 110 feet thick. Therefore, the pyritiferous shale of Schoharie can not be the Clinton, but probably is the thinned eastern edge of the lower part of the Cobleskill of the Litchfield section and not of the true Waterlime or Bertie formation." Even if we grant the thickness of the Cobleskill in Herkimer county as 30 feet, I am unable to see how the shales at Schoharie can be the thinned eastern edge of the lower part of the Cobleskill. If 19 feet represented the total thickness of the shales at Schoharie, this if added to the Manlius group of Schuchert would give about the same thickness as in Herkimer county. But as a matter of fact the shales below the Cobleskill at Schoharie have a greater thickness than that given to the Cobleskill in Herkimer county. The shales therefore can not represent the thinned eastern extension of the Cobleskill. Again in Schoharie county at Howes Cave the thickness of these shales is about 40 feet, which if added to the Manlius would give in Schoharie county a much greater thickness than the Manlius of Herkimer county as defined by Schuchert, thus showing more conclusively that the

shales of the Schoharie section are not the thinned edge of the Cobleskill of Herkimer county. I am of the opinion that the pyritiferous shales of the Schoharie section can not be of an age later than the Eurypterus beds of the Salina. In western New York we have the Cobleskill following directly the Eurypterus beds. The transition from the one to the other has previously been noted. Specimens of Eurypterus from the Salina waterlime of Erie county have associated with them Orthothetes interstriatus and Leperditia scalaris, two fossils common to the Cobleskill from Schoharie county westward. At Union Springs somewhat similar conditions exist, while in Herkimer county the Eurypterus beds are also in close proximity to the Cobleskill. These observations together with an examination of the section at Sharon Springs makes it difficult to conceive how the shales of the Schoharie section can be other than the Salina.

The formational term Manlius

The term "Waterlime group of Manlius" was introduced by Vanuxem[1] and takes its name[2] from the two layers of waterlime lying above the horizon of the blue limestones containing the typical Manlius limestone fauna. That is we have in New York State three distinct waterlime horizons, (1) the Salina waterlime below the Cobleskill, (2) the Rondout waterlime above the Cobleskill and (3) the Manlius waterlimes above the horizon containing what is now recognized as the Manlius limestone fauna. These upper layers of waterlime are of a somewhat local development, a fact that was not clearly brought out by Vanuxem and thus has arisen much confusion relative to the position of the several cement horizons and they have generally been treated without much regard to their stratigraphic relations. It should then be observed that included in the upper portion of the original Manlius is a waterlime and that the group was made to include all the waterlimes of the vicinity having a commercial value and not founded on any exact or even approximate stratigraphic or paleontologic determinations. It

[1] 3d Annual Report. 1839. p. 272.

[2] Geol. N. Y. 3d Dist. p. 110. N. Y. State Geologist. 15th An. Report. 1898. p. 267.

will thus be seen how the Manlius or Tentaculite limestone with its distinctive fauna came to be included with the waterlime group.

In the final report of the third district Vanuxem[1] does not use the term Waterlime group of Manlius but simply Waterlime group. The fauna cited by Vanuxem is that of the Tentaculite limestone of Gebhard and Mather. In 1899 when it became desirable to substitute for Tentaculite limestone a locality name, Manlius was the term chosen, and as defined by Clarke & Schuchert[2] it is the equivalent of the "Tentaculite limestone of Gebhard, Mather and later writers." Since it has been shown that at the type locality of the Manlius the Cobleskill was included with the Salina it is in the latter sense that I have used the term Manlius throughout and always as a unit, though I have realized that the original waterlime group in the eastern portion of the district provisionally included the Cobleskill. Vanuxem[3] there referred what is now recognized as the Cobleskill to the waterlime group or to an intermediate one which he did not attempt to define. The Manlius waterlime was never strictly defined and Hall[4] regarded it as a superior mass and above the strata containing the typical fauna. Consequently in the eastern portion of the fourth district the Onondaga salt group included all the strata up to the Manlius limestone. The Salina group as thus construed by Hall in this portion of the State may have had much to do with his calling the waterlime above the Cobleskill in Schoharie county Salina, since it occupies the same position stratigraphically with reference to the Manlius limestone.

Among the chief reasons advanced by Mr Schuchert for including the Cobleskill with the Manlius formation is the statement that the fauna of the Cobleskill does not contain a single Niagaran species, while it does contain a few species in common with the Manlius. I agree fully with Mr Schuchert that the Cobleskill and the Manlius contain species in common and I have

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[1] Geol. N. Y. 3d Dist. 1842. p. 110.
[2] Science, Dec. 15, 1899.
[3] Geol. N. Y. 3d Dist. 1842. p. 99.
[4] Geol. N. Y. 4th Dist. 1843. p. 128, 129, 141.

shown more species in common to the two formations than has he, but I do not agree with him that the Cobleskill is without Niagaran elements. The evidence I have presented indicates that the Cobleskill fauna is the last return of Guelph and Niagara species, and with the close of the Cobleskill the last Niagaran species disappears. The presence of these important Niagaran elements justifies one in keeping the Cobleskill formation distinct from the Manlius limestone.

The use of the term Manlius in the broad sense proposed by Mr Schuchert involves the duplication of terms[1], a feature which should be reluctantly accepted even if the stratigraphic and paleontologic interpretations could be considered correct.

Additional note

The fauna of the Cobleskill limestone of New Jersey, together with that of the underlying shales and limestones which are considered of Salina age has recently been described and illustrated by Weller.[2] The formations studied lie between the Rondout formation and the Bossardville limestone and are described under the name Decker Ferry formation, which Weller believes is the southern extension of what is now recognized as the Cobleskill limestone of Ulster county. This formation is best exposed in the Nearpass quarry near Port Jervis.

The number of species identified from this formation is 48. Six of the species previously known were described from the "Coralline" of Schoharie county by Hall, one Chonetes jerseyensis is found in the Cobleskill in Schoharie, Herkimer, Onondaga counties and at Cayuga lake. The species now recognized as Proetus pachydermatus Barrett has been obtained from the Cobleskill in Schoharie and Ulster counties. Eight of the species, Favosites pyriformis Hall, Halysites catenulatus Linn., Atrypa reticularis Linn., Leptaena rhomboidalis Wilck., Orthis flabellites Foerste, Reticularia bicostata Van., Pterinea emacerata Con. and Pterinea subplana Hall, are known from the Niagara of the interior but

[1] Science, Dec. 15, 1899. p. 975.

[2] Geol. Sur. N. J. Report on Paleontology. 1903. 3:62–75.

of these three are not identified with certainty. Two species are identified as Helderbergian forms — Pholidops ovata Hall and Rhynchospira formosa Hall. Among the species described as new Favosites corrugatus appears to be the same as F. niagarensis ? Hall (= F. helderbergiae var. praecedens Schuchert), a coral found abundantly in the Cobleskill. Another species Rhynchonella agglomerata is the same as Rhynchonella? litchfieldensis Schuchert. Both authors note a similarity of the latter species to the Niagaran form Camarotoechia neglecta Hall, to which species it was referred by the writer. Of the other forms described Cladopora rectilineata Simpson, Monotrypa corrugata Weller, and Wilsonia globosa Weller are found in the Wilbur limestone. A study of the Leperditia of the Ulster county section will undoubtedly show that it has a number of species in common with the Decker Ferry formation.

The evidence furnished by the study of the Decker Ferry fauna shows that only the upper beds may be definitely correlated with the Cobleskill limestone. Though Weller states that [*loc. cit.* p.18] "the Decker Ferry formation, as well as the subjacent beds down to the Medina formation, were probably contemporaneous with some portion or the whole of the Niagaran formations of the interior," it can not longer be so considered since it has been shown that in the section along Wheelock's creek in Herkimer county the original "coralline" limestone is separated from the Niagara by the Salina, the latter having a thickness of more than 400 feet. It is evident that whatever elements we find in the fauna of the Decker Ferry formation, which are suggestive of Niagaran age, they must be looked on as a late return of Niagaran species. The fact that the Decker Ferry formation was, in part, deposited in a basin distinct from that in the interior accounts for variations in the faunas of the stratigraphically equivalent beds in central New York.

Schuchert[1] includes all of the Decker Ferry formations under the term Manlius and Weller states that the Cobleskill at Ron-

[1] Am. Geol. Mar. 1903. p. 174.

dout is believed to represent the extension of the Decker Ferry formation, in which case the lower cement bed at Rondout may be correlated with the Bossardville limestone. It is clear however that the Bossardville limestone can not be correlated with the lower cement bed at Rondout since below the latter formation we have the Wilbur limestone with a fauna similar to the lower Decker Ferry fauna, which unites it with that formation and therefore the lower cement bed included between the Wilbur limestone and the Cobleskill limestone must be regarded as the stratigraphic equivalent of a portion of the Decker Ferry formation. The presence of Leperditia and other fossils in the Bossardville limestone which lies just below the Decker Ferry formation is indicative of the Salina age of this formation. In Ulster county the Bossardville limestone can not be recognized, but holding a similar stratigraphic position there is a series of soft greenish shales and quartzites which are usually referred to the Clinton formation, but which, together with the underlying red shales, as has been already suggested, may more properly be referred to the Salina.

DISTURBED FOSSILIFEROUS ROCKS IN THE VICINITY OF RONDOUT N. Y.

BY GILBERT VAN INGEN AND P. EDWIN CLARK

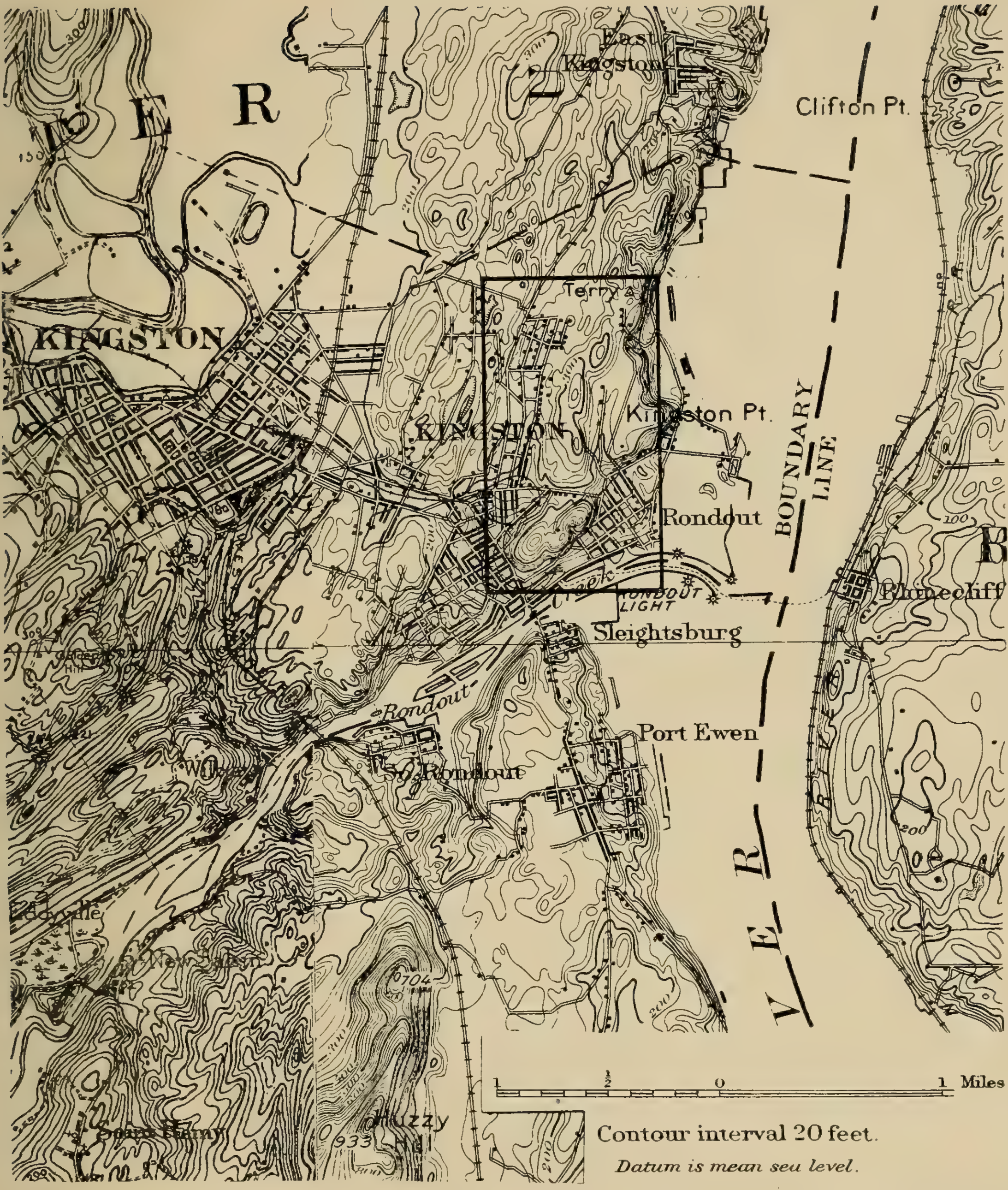
With 13 plates

The present paper describes briefly some of the more important stratigraphic and tectonic features observed by the authors during several years work in the vicinity of the cement mines at Rondout N. Y. It is a statement of progress of investigations now being carried on and is submitted with the object of bringing to the attention of geologists the highly interesting features of that region.

Several writers have published short papers on the region, but these have evidently been based on far too hasty examination, with the result that, while the more evident features have been described, numerous far more interesting though often less easily recognized phenomena have escaped attention, and the paleontology has been entirely neglected.

The particular district described embraces the hill called the Vlightberg in the city of Rondout, on which are located the quarries and mines of the Newark Lime & Cement Co., and also that wooded range of hills, referred to in this paper as the North hill fronting the Hudson river and extending from the Vlightberg northward to the Terry triangulation station of the United States Geological Survey situated on the hill west of Terry's brickyard, about 1 mile north of Kingston Point. This area, about 1½ miles long by ½ mile wide, has been the scene of quarrying operations during the past 60 years, and the openings, which in the Vlightberg are common along the eastern portion of the hill, afford unusual opportunities for observation of the interesting and complex tectonic phenomena in which the region abounds. Folds, faults and overthrusts can be seen in almost diagrammatic clearness. Up to the present time almost nothing has been done toward description of the fossil faunas of Ulster county, and as the Rondout region affords excellent opportunities for collecting fossils from the various members of the Siluric and Lower Devonic formations, a considerable

Plate I



Location map showing relation to surrounding country of area mapped in detail.

amount of material has been gathered by the senior author and the species have been identified to furnish the faunal lists accompanying this paper. One of the striking results of this paleontologic work is the discovery that a large number of those species heretofore considered to have been characteristic index fossils of the various members of the Helderbergian group are not confined to particular stages but range throughout two or more members of the series.

The senior author, Mr van Ingen, first became acquainted with the region in 1888, and has visited it frequently since that date. The junior author, Mr Clark, has been superintendent of mining operations for the Newark Lime & Cement Co., for several years, and in that capacity has had fine opportunities to study the folding and faulting of the formations beneath the surface. In many cases the underground observations, supplementing the surface work, have enabled the authors to satisfactorily explain difficult points which could not have been solved by observations on the surface alone.

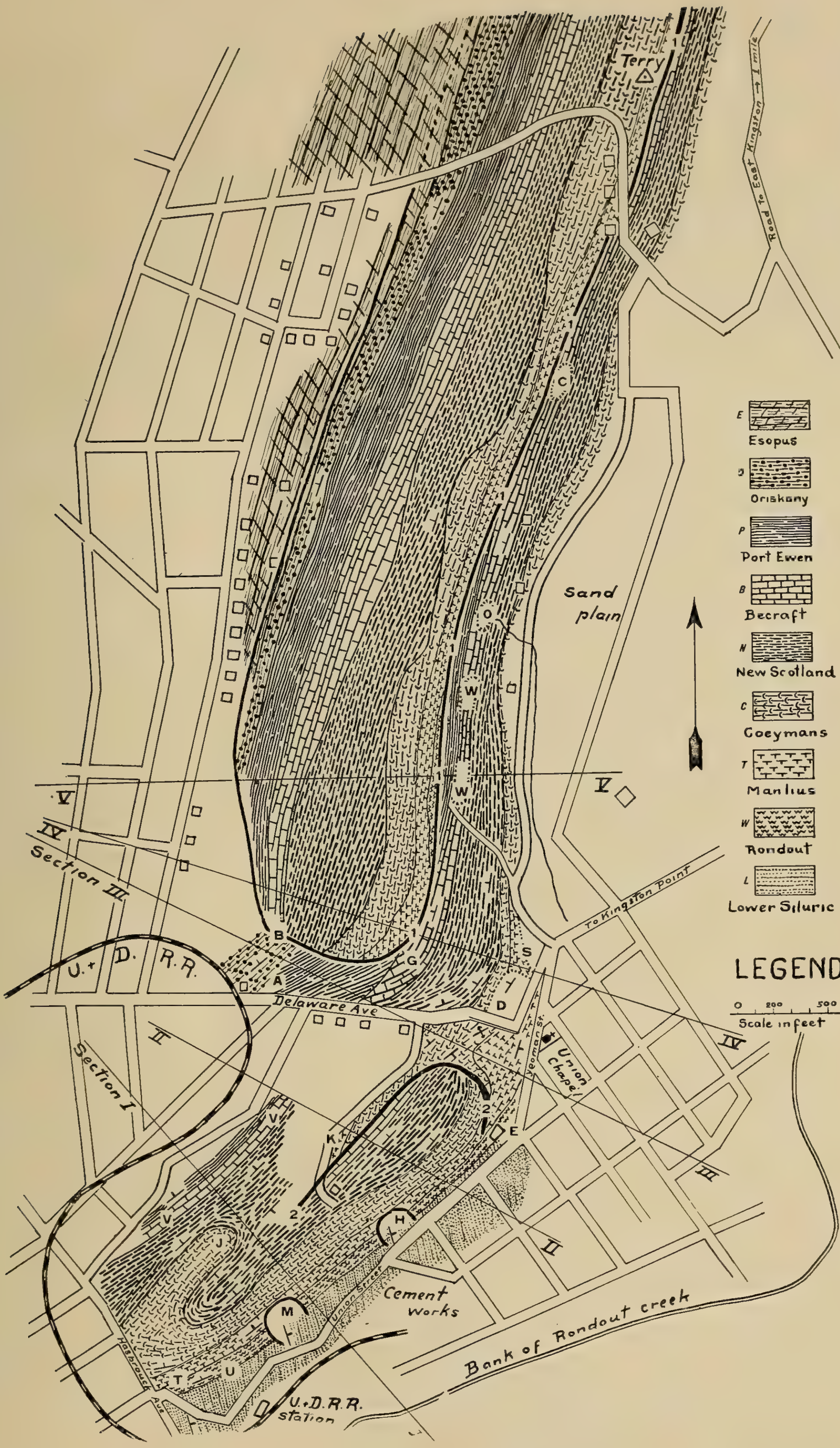
The structure is in places so complicated by excessive folding and faulting that it has been found necessary to prepare a large scale map. This map, still in manuscript, with a scale of 100 feet to 1 inch is based on stadia survey with the stations generally less than 100 feet apart, and all outcrops are tied up to stations. In this way the construction of parallel cross sections at frequent intervals will be facilitated, and reproduction of the tectonic features of the region by a series of models will be made possible.

While both authors have been closely associated in the study of the structural features, Mr van Ingen alone is responsible for the paleontologic portion. The authors wish to acknowledge their indebtedness to Mr Calvin Tomkins, president of the Newark Lime & Cement Co., for many favors extended them during the progress of their investigations.

The visitor who approaches Rondout by boat on the Hudson river has his attention attracted by a prominent hill which rises steeply back of the lower town to hights of 250 to 300 feet. This is the Vlightberg and the steep cliffs on the side fronting the river are largely due to the quarries opened along the beds of

waterlimestone which have during the past sixty years or more been mined here for use in cement manufacture. The Vlightberg, with a length of about ½ mile and a width of ⅛ mile, lies with its longer axis in a northeasterly direction in the city of Rondout between Hasbrouck avenue on the southwest and Delaware avenue on the northeast, and constitutes a prominent ridge which separates the southeasterly portion of the city of Kingston into two parts, an eastern part known locally by the old name of Ponckhockie, built on the plain near the river, and a western part, Rondout, occupying the valley south and west of the Vlightberg. To the northward of the Vlightberg, the ridge is continued through the wooded " North hill," for about 2 miles to the vicinity of East Kingston where it becomes less prominent. At various points throughout its course its eastern face is very steep, as at " steep rocks," and near Terry's brickyard, and at a point east of Cloonan's quarry, indicated on the map by C, Delaware avenue passes across the ridge through a narrow east and west gap. The southwest end of the Vlightberg terminates in steep cliffs overlooking Hasbrouck avenue, to the southwest of which street the land surface is low and hidden under the buildings of Rondout. The western slopes of the Vlightberg and of the North hill, as we will designate that portion of the ridge lying north of Delaware avenue, while locally steep, are not so high and do not present such precipitous bluffs as are seen on the eastern slopes. All along the western side of the Vlightberg ridge is a valley about ¼ mile wide, with its bottom at levels varying from 75 to 200 feet A.T., which separates the Vlightberg ridge from the plain on which the city of Kingston is built. The eastern edge of this plain is formed by the Esopus grit, and the Onondaga limestone is exposed on it in a series of low anticlinals forming a belt about ¾ mile wide. The city of Kingston proper lying still farther west is built on the alluvial plain of the Esopus valley, which, with an elevation of about 175 feet, extends from near Stoneridge, about 8 miles southwest of Kingston, to Mt Marion, 7 miles north of the city. This plain is underlain by shales of the Marcellus and Hamilton formations deeply buried beneath alluvial deposits.

Plate 2



Map of the small area inclosed in quadrangle shown on plate 1. The Vlightberg includes the area south of Delaware avenue; the North hill, that between Delaware avenue and the crossroad near Terry bench mark.

Kingston and Rondout are located on the southerly continuation of that zone of Appalachian folding to which, in the vicinity of Catskill, Professor Davis applied the name of the Little Mountains, and the geologic formations of Siluric and Lower Devonic age are here exposed in more or less parallel folds of northeasterly trend. The particular district in which we are interested, that lying within the small quadrangle on the accompanying location map [pl. 1], lies at the eastern edge of the Little Mountains along the line of maximum folding, and at the apex of the angle which marks the change of trend of the folds from a southerly to a more southwesterly direction. This fact will be better understood by reference to the geologic map of New York State on which the exposure of the Helderberg limestones is shown to bend at Rondout sharply to the southwest through an arc of about 25 degrees. This change in the direction of outcrop is not due to erosion only, but is caused in great extent by variation in the directrices of the folds and thrusts, and is related to the presence of numerous interlocking thrust planes of small width which have been observed in the cement mines and in the quarries of the Becraft limestone.

The geologic map [pl. 2] is a sketch map based on part of the Rhinebeck quadrangle of the United States Geological Survey topographic atlas, and is approximately correct. The areal distribution of the formations is indicated by symbols which are used also in the cross sections. The italic capital letters on the cross sections are explained in the legend of the map. Certain localities to which frequent reference is made in the text are indicated on the map, by letters, as follows.

A Gross's residence on Delaware avenue

B Becraft abutting against Oriskany north of Gross's residence

C Cloonan's quarry on the first Becraft vein, east side of North hill

D Delaware avenue quarry

E Engine house at north end of Vlightberg

G Gross's quarry in Becraft limestone on Delaware avenue

H Hill quarry on Glory hole vein on east side of Vlightberg

J Anticline on Vlightberg near western side

K Outcrop of Manlius limestone at side of road leading to house on top of Vlightberg

M Middle quarry on Glory hole vein on east side of Vlightberg

O Old quarry on Becraft limestone east side of North hill

S Spring quarry at junction of Delaware avenue and Yeoman street

T Taylor's corner quarry at south end of Vlightberg, on Hasbrouck av.

U Unconformity exposed near Taylor's corner

V Vertical cut in Becraft limestone, west side of Vlightberg

W White lime quarry on Becraft limestone, east side of North hill

Generalized section

The geologic formations exposed in the Vlightberg and in the North hill range from Champlainic (Lower Siluric) to Ulsterian (Middle Devonic) in age, and their order of sequence and thicknesses are shown in the following table:

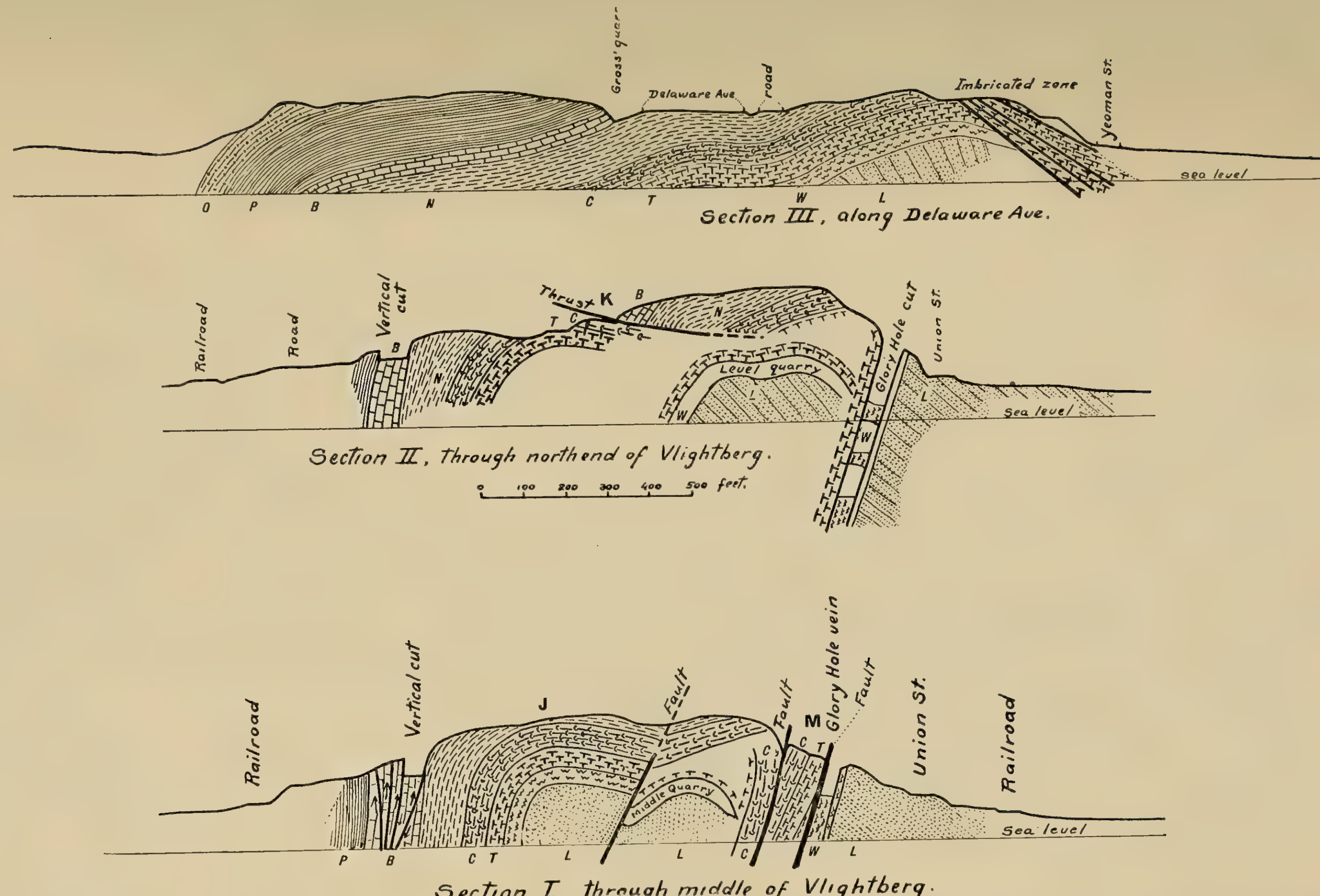
				Feet
			Onondaga limestone	75
Middle Devonic	Ulsterian		Esopus grit	300
	Oriskanian		Oriskany sandstone and limestone	60
			Port Ewen limestone	150+
Lower Devonic	Helderbergian		Becraft limestone	40
			New Scotland shale	100+
			Coeymans limestone	50
			Manlius limestone	45
		cement series	Rondout waterlime	15
Upper Ontaric or Upper Siluric	Cayugan	cement series	Cobleskill limestone	—1
		cement series	Salina waterlime	10
			Wilbur limestone	5—7
		Unconformity		
Neochamplainic or Lower Siluric	Mohawkian		Normanskill shale	1 000+

STRATIGRAPHY AND PALEONTOLOGY

Champlainic

The substructure on which lie the Ontaric and Devonic formations of the region is a mass of highly tilted and often much contorted sandstones and shales, usually referred to the "Hudson river group," and probably equivalent to the Normans kill beds of the upper Hudson river valley. In constitution these

Plate 3



Structure sections through the Vlightberg. In section 3 the Rondout beds, marked W should have been drawn as extending with a southeasterly dip (to the right) below the lowest fault plane of the imbricated zone.

rocks are graywackes, or quartz sandstones with argillaceous cement and with little lime content. In color they are, when fresh, olive gray and, when weathered, dark gray, brown or blackish. They outcrop along the eastern base of the Vlightberg, have been exposed in some of the underground workings specially in the Level and the Middle quarry, and they may be seen to better advantage on Kingston Point, along the right bank of Rondout creek at South Rondout, and in the high hill known as Huzzy hill about 2 miles south of Kingston. Their thickness can nowhere be accurately measured, but it is certainly over 1000 feet. At some points thin layers of black shale are intercalated in the sandstone, as at the Middle quarry and on Kingston point. Some of the heavier layers of sandstone have their surfaces dotted with flattened pebbles of dark shale from ½ to 2 inches in diameter, which appear to have been soft mud when they were deposited there. These sandstones seem to have been largely of shallow water or even of beach origin, for cross bedding is common and at some points, notably at the entrance to the Middle quarry, the thinly bedded sandstones with shale partings show ripple marks and sun cracks. Fossils are rare. Some thin calcareous layers 1 to 3 inches thick and very difficult to find, contain abundant water-worn individuals of Plectambonites sericea, and Dalmanella testudinaria; and a few graptolites have been found in the shale on Kingston point.

The Champlainic sandstones are found, in all cases where the contact has been exposed, to be sharply and distinctly unconformable to the overlying limestones of the Upper Ontaric (Silurian), as described below.

Ontaric or Upper Siluric

Only the upper members comprising the Cayugan series of the Ontaric system are represented in the Rondout section; the lower members, including the Niagaran and Oswegan series, are absent and their time periods are indicated by marked unconformity between the upper Ontaric limestones and the subjacent Champlainic sandstones. The Ontaric formations may be grouped under three heads; the upper Manlius limestone; the

middle cement series, comprising the Rondout, Cobleskill and Salina waterlimestone; and the lowermost Wilbur limestone. These formations are exposed along the steep eastern slopes of the Vlightberg and North hill where they are found dipping at high angles into the hills to the northwest; and some portions of the series, specially the Manlius limestones, are exposed above the overthrust on the North hill, and also below the Vlightberg overthrust plane along the road running to the top of the Vlightberg at the point marked K on the map.

Wilbur limestone

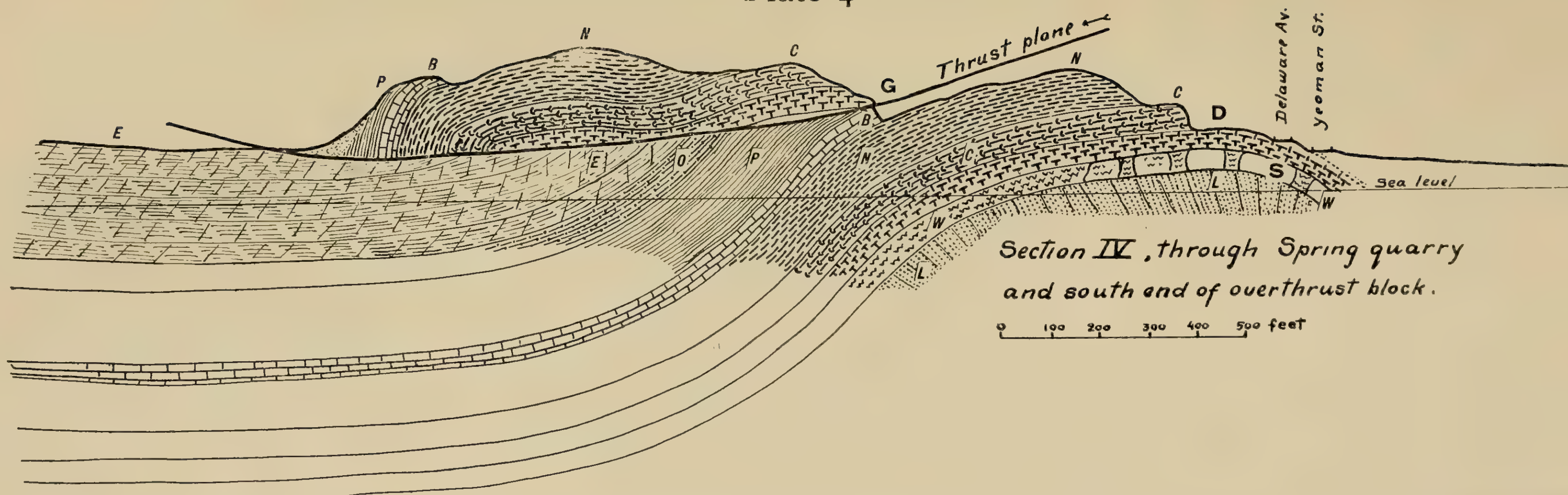
This lowest member of the upper Ontaric limestone series lies unconformably on the eroded edges of the tilted Champlainic sandstones. It is a dark colored argillaceous limestone 5 to 7 feet thick, which on weathering turns brown. In places it is highly fossiliferous, containing corals, crinoid fragments, brachiopods, mollusks and some trilobites. The fauna of this limestone, which has long been known as the "coralline" and which has recently been termed Wilbur limestone, is described in Mr Hartnagel's paper in another part of this volume, and details of the unconformity at the base of the Wilbur beds are described below [p. 1209].

Cement series, comprising the Salina, Cobleskill and Rondout beds

These cement beds have been variously called Salina, Waterlime, Manlius, Onondaga etc., and till recently [see Hartnagel's paper on Preliminary Observations on the Cobleskill ("Coralline") Limestone of New York, p. 1109] no attempt has been made to definitely correlate them with any portion of the Siluric section of western and central New York. They consist of nine distinctly marked layers of limestone aggregating about 32 feet in thickness.

The following detailed section of the strata exposed in the Spring and Delaware avenue quarries where the softer beds have suffered the least amount of crushing, and which shows the relations of the cement beds to each other and to the under and overlying formations, may be taken as typical of the Vlightberg vicinity. The names given to the cement beds are those applied by the miners.

Plate 4



Cross section through south end of North hill at the Spring and Delaware avenue quarries, showing eastern anticline and White lime quarry overthrust.

Detailed section of the formations exposed in the Spring and Delaware avenue quarries

(Stations 301 and 325)

Helderbergian	Coeymans 50′,7″	25	Shaly limestone	4′,0″
		24	Shaly limestone	11′,6″
		23	Cherty limestone	12′,1″
		22	Cherty limestone	11′,0″
		21	Hard limestone	7′,0″
		20	Basal, marly, transition	4′,10″
Cayugan	Manlius 42′	19	Hard dove, massive	6′,4″
		18	Light gray compact	6′,3″
		17	Stromatopora, upper bed	7′,6″
		16	Stromatopora, bottom	5′,5″
		15	Dark blue with gray seams	5′,8″
		14	Dark blue	3′,10″
		13	Thin banded	2′,5″
		12	Gray band	4′,6″
	Rondout 19′,6″	11	Paving block or mud crack	3′,3″
		10	Prismatic or five point	4′,4″
		9	Leperditia bed	2′,1″
		8	Curly, variable	8″–19″
		7	Soft gray cement	3′,3″
		6	Hard gray cement	5′,0″
	Cobleskill	5a	Middle ledge	7″
	Salina 9′, 7″–11′,2″	5	Hard black cement	4′,8″
		4	Soft black cement	4′,5″
		3	Footledge	6″–2′,0″
	Wilbur 5′–7′	2	"Coralline"	5′–7′,0″
	Unconformity			
Upper Champlainic	Mohawkian	1	Normanskill sandstone	1000′+

The Champlainic sandstones and the Wilbur limestone are not well shown in this section.

Salina

Comprising the dark cements

3 The "footledge," of hard, fine grained, almost black limestone, varies from 6 to 24 inches in thickness. The upper 6 or 8 inches are of exceptionally fine grain and are used for cement. The lower portion is rough and fossiliferous containing crinoid fragments and Tentaculites which are best seen when the stone happens to have gone through the kilns.

4 Soft black cement. A solid bed, 4 feet 5 inches thick, of dark limestone of finer grain than 3, and with some fossils in middle portion.

5 Hard black cement, 4 feet 8 inches thick, is much like 4, but it is somewhat harder, breaks with a more conchoidal fracture, and it often has irregular dark blotches on an olive-gray ground.

Cobleskill

5a The middle ledge is a 7 inch band of somewhat shaly slightly more calcareous limestone that can usually be separated from the top of the hard black cement as a distinct bed. This band is highly fossiliferous, but the fossils can scarcely be seen in the fresh rock, and they appear best after the rock has been burned in the kilns. A large species of Leperditia is abundant, and Orthothetes hydraulicus and Rhynchonella lamellata are present. This middle ledge of the Vlightberg is, as demonstrated by Hartnagel, the attenuated eastern extension of the Cobleskill limestone of the Schoharie section.

Rondout beds

Comprising the light cements

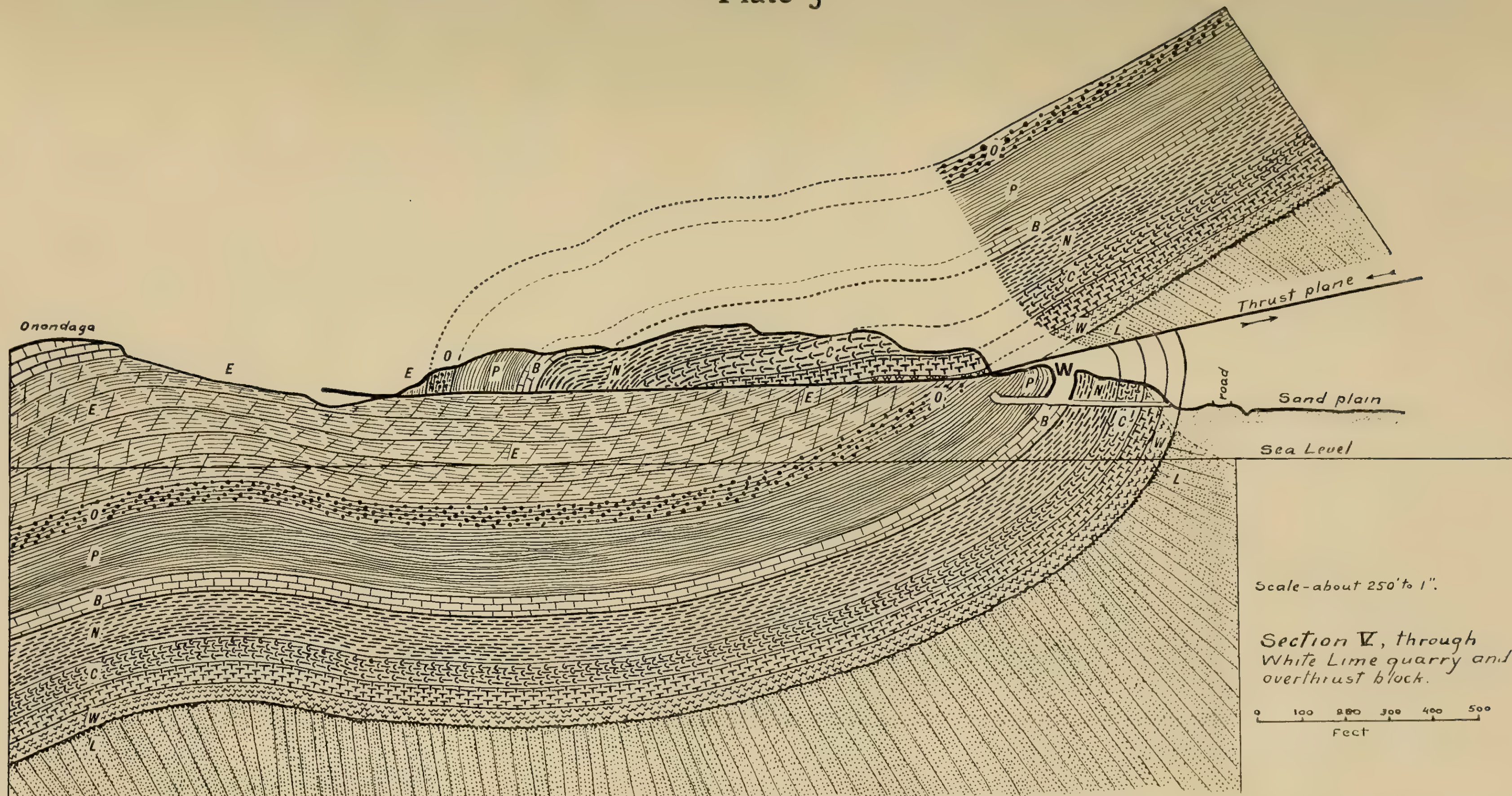
6 Hard gray cement, 5 feet thick, is a solid bed which on cross section shows horizontal bands of olive-green on a lighter gray ground. The rock has a splintery fracture; is of very fine grain at top and center, and at bottom is quite coarse.

7 Soft gray cement, 3 feet 3 inches thick, has a more even tone of slightly darker gray than 6, and is of finer grain and more conchoidal fracture.

8 The "curly" is a 19 inch band of dark gray, fine grain cement rock with undulating lamination, which is usually much sheared and crushed to a dark powdery mass by lateral movement of the overlying formations.

It is to be noted that in general the lower part of each cement layer is of coarser grain than the upper part, except in the hard black cement which is a smooth stone throughout. Some quartz sand is found in all the layers excepting the hard black. It occurs in the form of well rounded minute grains of limpid quartz scattered irregularly through the limestone, and from its resemblance to the wind-blown sand of deserts, it may be considered to have been brought by the wind from some near-by arid lands which bordered or inclosed the mud flats of Neontaric time.

Plate 5



Section through North hill at White lime quarry, showing overthrust and westward drag of beds below thrust plane at east side of hill. The dotted lines above the land surface and the block with symbols at right upper corner of section indicate the position of the strata after faulting and before erosion had produced the present topography.

9 The Leperditia bed, about 25 inches thick, forms the roof in most of the underground cement workings. It is a persistent band of tough black shaly limestone, and is full of the shells of Leperditia alta, which show plainly on the gray weathered surfaces of the thin layers into which this formation splits. The Leperditia bed is well exposed in the hanging wall of the several quarries on the Glory hole vein along the eastern slope of the Vlightberg, and also at the old cement opening on the hillside over the White lime quarry on the North hill. At the latter point the following species were obtained: Leperditia alta (aa), Beyrichia sp.? (aa), Modiolopsis dubius Hall, and Spirifer vanuxemi.

10, 11 Above the Leperditia bed are two bands of yellowish limestone, aggregating 7 feet, 7 inches in thickness, which break up into polygonal blocks [*see* pl. 6] formed apparently by shrinkage cracks similar to those seen in drying mud, and this resemblance is rendered more striking by the concave plates into which the blocks readily split along planes parallel to the stratification. Local names are given to different portions of these two beds, which might perhaps more properly be considered as a single formation. The lower 22 inches is called the "streaked" because of its horizontal dark lines; the "prismatic" or "five point," 32 inches thick, breaks up into mostly pentagonal blocks 4 to 6 inches in diameter; the "paving block" or "mud crack," 15 inches thick, breaks into larger polygonal blocks of 6 to 10 inches diameter; and an uppermost 24 inch layer consists of gray weathering impure silicious limestone. Portions of these two beds make good cement but as a rule they are not quarried because the rock above them does not form a safe hanging wall or roof.

Manlius limestone

Beds 12–19

The Manlius limestone, aggregating about 42 feet in thickness, consists of eight beds of generally black or bluish gray limestone, with many intercalated thin beds that weather to a light gray. The lower beds, 12 to 16, contain the species so characteristic of the Manlius fauna: Leperditia alta,

Spirifer vanuxemi, and Stropheodonta varistriata. A few of the gray weathering bands just below and just above the Stromatopora bed contain a gastropod fauna. Bed 17, with a thickness of 7 feet, 6 inches, is a veritable coral reef, consisting almost entirely of species of Stromatopora, which are found also more sparingly in the underlying bed, 16. The association between the gastropod fauna and the coral reef is noteworthy. The uppermost layer of the Manlius, 19, is a heavy bed of fine grained, dove-colored silicious limestone, 6 feet, 4 inches thick, and is apparently barren of fossils. It forms the lowest bed of the Delaware avenue quarry. The upper surface of this dove limestone is curiously irregular and its contact with the dark overlying basal member of the Coeymans limestone is very sharp. There appears some evidence that the surface of the Manlius was slightly eroded before the Coeymans was deposited on it. Where exposed to the weather for a short time the black limestone can be readily separated from the dove-colored rock and the contact is then seen to be of very undulating nature, as if the soft calcareous mud of the Manlius had been eroded by the currents of the transgressing Coeymans sea when the latter advanced on the sinking mud flats or lagoons of the Manlius continental shelf.

FAUNA OF THE MANLIUS LIMESTONES

a=abundant aa=very abundant c=common r=rare rr=very rare

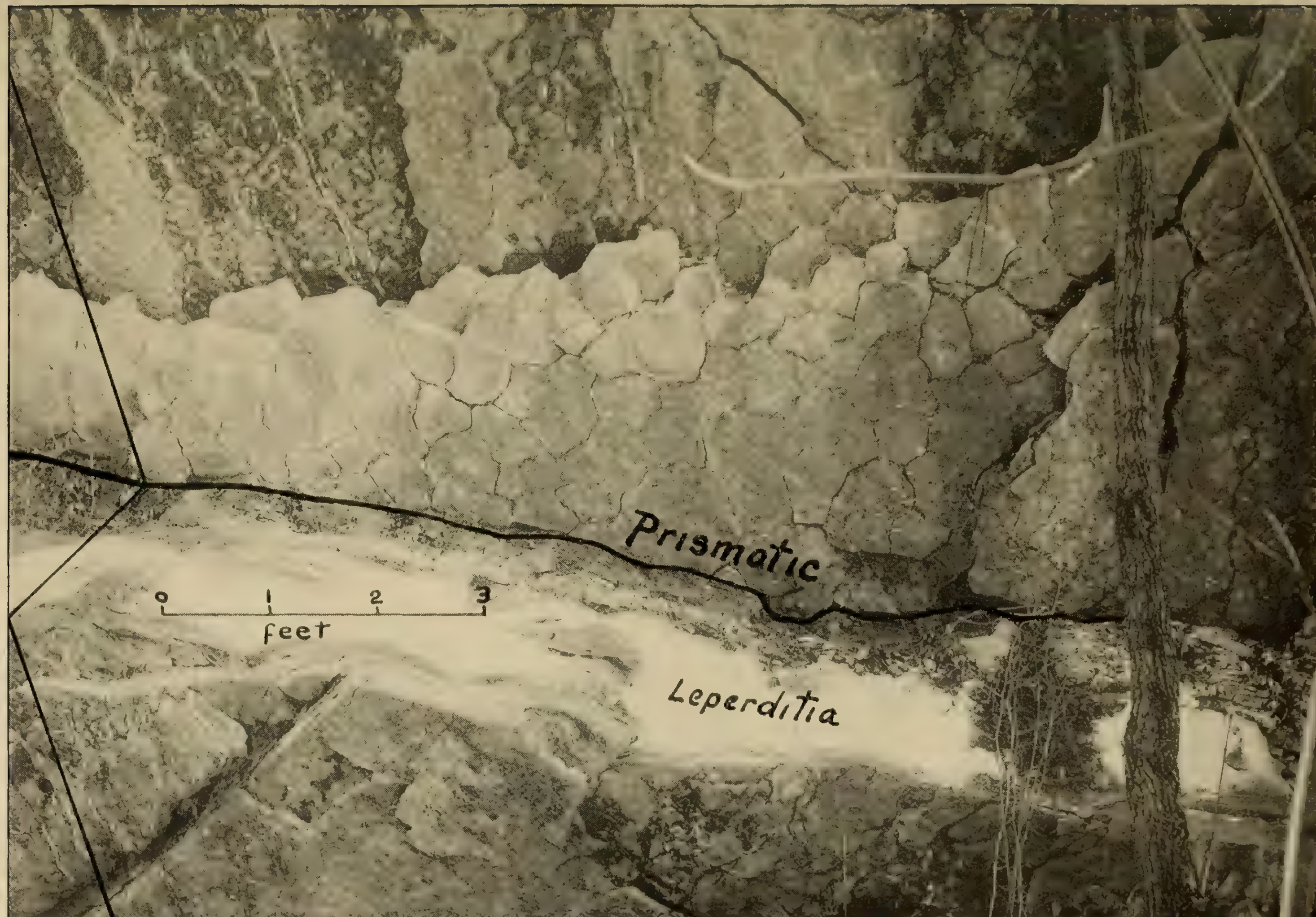
Gastropod layer just below the Stromatopora bed.

Loxonema fitchi *Hall*, c
Holopea pervetusta (*Conrad*), c
H. subconica *Hall*, c
Loxonema *sp.*?
Murchisonia minuta *Hall*
Hormotoma, small species
Modiolopsis dubia *Hall*
Holopea elongata *Hall*
Laevidentalium *sp.*?
Spirifer vanuxemi *Hall*, r
Leperditia alta *Conrad*, c
Holopea antiqua (*Vanuxem*)
Zaphrentis *sp.*?

Gastropod layer just above the Stromatopora bed.

Spirifer vanuxemi *Hall*, c
Tentaculites gyracanthus (*Eaton*), c
Stropheodonta varistriata *Conrad*, c
Leperditia alta *Conrad*, c
Ostracods, numerous specimens of two or three small species
Hormotoma, small species
Holopea elongata *Hall*

Plate 6



Under surfaces of Leperditia bed and "prismatic" cement bed, showing fossil mud cracks in the cement layer. The view is taken from below looking up at the overhanging beds, and the lines at the left of the picture indicate the relief of the surface. For description see page 1185

Dark limestone beds of upper and lower part of Manlius. The fauna of these beds of similar sediments seems both below and above the Stromatopora bed to be the same.

Leperditia alta *Conrad,* a
Spirifer vanuxemi *Hall,* a
Stropheodonta varistriata *Conrad,* c
Loxonema *sp.*?
Ilionia sinuata *Hall,* r

Devonic formations

The Devonic formations exposed in the Vlightberg and on the North hill are of the Helderbergian, Oriskanian and Ulsterian series, ranging from the Coeymans limestone on the east to the Esopus grit on the west side of the ridge. The Onondaga limestone is not found on these ridges, but is exposed farther to the westward on the edge of the Kingston plain.

Coeymans limestone

A series of heavy beds of dark gray limestone, aggregating about 49 or 50 feet in thickness, is exposed along the crest of the bluff on the east side of the Vlightberg and North hill, and also forms a ridge of some prominence above the White lime quarry overthrust, which may be traced through the woods from the vicinity of Gross's quarry to beyond Terry bench mark. The entire series is seen to best advantage in the Delaware avenue quarry where can also be seen the abrupt lower contact with the Manlius and the gradual upward transition into the overlying more shaly New Scotland beds. The component parts of the Coeymans limestone are as follows, in ascending order.

20 Basal bed. 58 inches of irregular, marly limestone of dark gray color, which on weathering readily breaks up into small nodular pieces. It is full of fossils; crinoid fragments and brachiopods are common, and Lichenalia specimens of all stages of growth are particularly characteristic of this zone. On weathered joint planes this rock somewhat resembles the Stromatopora bed. The best places to collect fossils from this bed are in the Delaware avenue quarry, and on the first ridge west of the old cement workings above the White lime quarry.

FAUNA OF THE COEYMANS LIMESTONE

20 Lower basal bed

Lichenalia torta *Hall*, very abundant. Interesting series of growth stages of this bryozoan can be obtained in the limestone back of the White lime quarry. The colony starts as a cornucopialike zoarium, which sometimes attains a length of 1½ inches before it begins to assume an irregularly flabellate form. An adult frond nearly 6 inches in length was obtained in the Delaware avenue quarry.
Spirifer cyclopterus *Hall*, c
S. concinnus *Hall*, c
S. perlamellosus *Hall*, r
Rhipidomella oblata *Hall*, c
R. oblata emarginata *Hall*
Uncinulus mutabilis *Hall*, c
Strophonella punctulifera (*Conrad*), c
S. varistriata (*Conrad*), c. Both flat and highly convex varieties
Gypidula galeata (*Dalman*), c. Not so common in this bed as in the overlying beds. Form very variable, from large weakly plicate to small strongly plicate forms. Also individuals with bifurcating folds
Chaetetes sphaericus *Hall*, c
Meristella laevis (*Vanuxem*), r
Rhynchotrema formosum (*Hall*), r
Rhynchospira globosa *Hall*, r
Rhynchospira *sp. nov.*, c
Orthothetes woolworthanus *Hall*, r
Spirifer macropleurus (*Conrad*), r
Megambonia *sp.*? c
Strophonella leavenworthana, r
Leptaena rhomboidalis (*Wilck.*), c. The concentrically corrugate form with a high geniculation, like that figured in *Palaeontology of New York*, v. 3, pl. 19, fig. 1k
Atrypa reticularis *Linne*, r. Small individuals with regular fine radial ribs
Actinopteria textilis (*Hall*), r
Stropheodonta becki *Hall*, r
S. *cf.* planulata *Hall*, r
Dalmanella subcarinata *Hall*, r
Favosites helderbergiae *Hall*, common in very lowermost portion
Pholidops *sp.*? r
Rhynchonella semiplicata *Conrad*, c
Bronteus barrandii *Hall*, r
Proetus protuberans *Hall*, c
Dalmanites pleuroptyx (*Green*), c
D. micrurus (*Green*), r
Phacops logani *Hall*, c
Nucleospira *sp.*? r
Cyrtina dalmani *Hall*, r
Orthoceras *sp.*? r. Annulated type
Bryozoa and some ostracods, unidentified.

21 Seven feet of massive dark gray limestone containing fossils which are extremely difficult to extract.

Lichenalia torta *Hall*, c
Dalmanites micrurus (*Green*), c
Gypidula galeata *Dalman*, c
Actinopteria textilis (*Hall*), c
Lamellibranch, large, *gen. et sp. nov.*?

22 Heavy bed of limestone, 11 feet thick, full of large crinoid stems. The upper part of this bed has much black chert in thin bands. A t r y p a r e t i c u l a r i s and the sponge, Hindia, are common.

Atrypa reticularis *Linne*, a
Gypidula galeata *Dalman*, c
Hindia fibrosa (*Roemer*), a
Favosites helderbergiae *Hall*, c
Uncinulus nucleolatus *Hall*, c
Sponge, *gen. et sp.*?

23 A dark limestone in massive bed 12′, 1″ thick with chert in the lower 4 feet. Fossils are abundant.

Atrypa reticularis *Linne,* a	Anastrophia verneuilli *Hall,* r
Hindia fibrosa (*Roemer*), a	Dalmanella perelegans *Hall,* c
Gypidula galeata *Dalman,* a paucplicate form	Strophonella punctulifera (*Conrad*), r
Gypidula galeata, large form with coarse bifurcating plications	

24 At the top of the quarry a layer 11′, 6″ thick assumes a more shaly structure and shows fairly well marked cleavage. It forms, together with the next overlying bed, 25, a transition zone from the Coeymans to the New Scotland limestones. It is full of Gypidula and other fossils, as listed.

Gypidula galeata *Dalman,* aa	Orthothetes *sp.*?
Leptaena rhomboidalis (*Wilck.*), c	Dalmanella perelegans *Hall,* c
Atrypa reticularis *Linne,* a	Uncinulus nucleolatus *Hall*
Stropheodonta varistriata (*Conrad*), c	Lichenalia torta *Hall*
Hindia fibrosa (*Roemer*), c	Spirifer octocostatus *Hall* (?)
Leptaenisca concava *Hall* (?) r	Chaetetes sphaericus *Hall*
Rhynchospira globosa *Hall,* r	Strophonella punctulifera (*Conrad*)
Spirifer cyclopterus *Hall,* r	Rhipidomella, *small species*

25 Shaly, dark gray, argillaceous limestone with strongly developed slaty cleavage, 4+feet, thick, showing in the hill slope above the top of the quarry. Lithologically this rock resembles closely the lower portion of the New Scotland beds farther up the hillside. It abounds in fossils, of which the most abundant is G y p i d u l a g a l e a t a. It is considered to be the uppermost layer of the Coeymans limestone, as above this the index fossil, Gypidula, becomes rare or is entirely wanting. (Museum no. 3300)

Gypidula galeata *Dalman,* aa	Dalmanella perelegans *Hall,* c
Atrypa reticularis *Linne,* a	Nucleospira ventricosa *Hall,* r
Uncinulus nucleolatus *Hall,* c	Parazyga deweyi *Hall,* r
Atrypina imbricata *Hall,* c	Lichenalia torta *Hall,* r
Spirifer perlamellosus *Hall*	Platyceras *sp.*? r
Bilobites varica (*Conrad*), c	

New Scotland beds

(Formerly Catskill shaly and Delthyris shaly limestone; also Lower shaly of Davis)

The thickness of this formation is given as 100 feet, but this figure is based on estimate only, as exact measurement of the entire formation has not yet been possible. At no single point

can a continuous section from top to bottom be examined, and the physical characters of the formation are such that it has suffered great deformation, which is manifested in the pronounced slaty cleavage, numerous small folds and local thrusts, all of which render determination of its thickness a matter of much difficulty. Portions of the New Scotland beds are exposed at several points. Among the best exposures are those at the south end of the vertical cut on the west side of the Vlightberg; along the top of the Vlightberg; on the north side of Delaware avenue; between the Delaware avenue quarry and Gross's lime quarry; in the foot wall of the White lime quarry; and in a low bluff at the west side of the small swale that extends northwestward from the Old quarry. This formation consists of dark gray shaly limestone bands alternating with frequent thin seams of gray semicrystalline limestone. At some points, as on Delaware avenue, sandy shales are present in the middle of the formation. The lower portion has considerable chert, which is often associated, as in the underlying Coeymans, with an abundance of sponges. The upper portion of the New Scotland graduates by increased thickness of the limestone bands, which contain abundant "scutellae," into the lower portion of the Becraft limestone. This transition is very gradual and may be well seen in the White lime quarry, in the Old quarry, in the Vertical cut, and in the quarry which follows the outcrop of the Becraft limestone along the face of the hill at the northern end of the West Shore Railroad bridge at Wilbur.

Several feet of the upper portion of the New Scotland beds are so limy, that they might with equal propriety be included with the overlying Becraft limestone, but the line between the two formations has been drawn at a well marked division plane, which indicates a stoppage or temporary change in the sedimentation.

FAUNA OF THE LOWER NEW SCOTLAND BEDS

From the ledge northwest of the Old quarry

Orthothetes woolworthanus *Hall*, aa
Strophonella punctulifera (*Conrad*), c
Rhipidomella oblata *Hall*, c
Crinoid stems, aa
Isochilina, *minute species*, aa
Chaetetes sphaericus *Hall*, c
Stropheodonta becki *Hall*, aa
Leptaena rhomboidalis (*Wilck*), aa
Phacops logani *Hall*, c
Dalmanites pleuroptyx (*Green*), c

Spirifer cyclopterus *Hall*, c
S. macropleurus (*Conrad*), c
Proetus protuberans *Hall*, r
Eatonia medialis (*Vanuxem*), c
Acidaspis tuberculatus (*Conrad*), r
Actinopteria textilis (*Hall*), c
Platyostoma *sp.*?, r
Eatonia peculiaris (*Conrad*), c
Meristella laevis (*Vanuxem*), c
Dalmanella perelegans *Hall*, c
Spirifer perlamellosus *Hall*, c
Hindia fibrosa (*Roemer*), c
Strophonella *sp.*?
Lichenalia torta *Hall*, c
Atrypina imbricata *Hall*, c

FAUNA OF THE MIDDLE NEW SCOTLAND BEDS

From Delaware avenue, between the Delaware avenue quarry and Gross's quarry

Leptaena rhomboidalis (*Wilck*), a
Orthothetes woolworthanus (*Hall*) aa
Strophonella radiata (*Vanuxem*), aa
Dalmanella perelegans *Hall*, c
Anoplotheca concava (*Hall*), c
Acidaspis tuberculatus (*Conrad*), c
Spirifer perlamellosus *Hall*, c
Dalmanites pleuroptyx (*Green*), r
Uncinulus vellicatus *Hall*, r
Cyrtoceras, *small species*, rr
Meristella, *sp. indet.*, r
Phacops logani *Hall*, r
Eatonia medialis *Hall*, c
Pholidops *sp.*?, r
Actinopteria textilis (*Hall*), r
Chonetes *sp.*?, r
Lichenalia torta *Hall*, c
Chaetetes sphaericus *Hall*, branching form, c
Platyostoma, 2 species, r
Strophonella punctulifera (*Conrad*), r
Stropheodonta arata *Hall*, c
S. beckii *Hall*, c
Rhynchonella bialveata *Hall*, r
R. inutilis *Hall*, r
Strophonella cavumbona *Hall*, c
Anoplia nucleata *Hall*, r
Rhipidomella oblata *Hall*, c
R. discus *Hall*, r
Isochilina, *small*, c

FAUNA OF THE UPPER NEW SCOTLAND LIMESTONE

From just below the foot wall of the Becraft limestone at the White lime quarry

Spirifer cyclopterus *Hall*, aa
Rhipidomella oblata *Hall*, c
Proetus *sp.*?, rr
Stropheodonta *sp.*?, r
Rhynchonella transversa *Hall*, aa
Spirifer concinnus *Hall*, c
Ostracods, *several species*, c
Dalmanites pleuroptyx (*Green*), r
Rensselaeria mutabilis *Hall*, r
Actinopteria textilis *Hall*, r
Gypidula pseudogaleata *Hall*, r
Stropheodonta becki *Hall*, c
Aspidocrinus scutelliformis *Hall*, aa
Atrypa reticularis *Linne*, c
Orthothetes woolworthanus *Hall*, c
Rhynchotrema formosum *Hall*, a
Meristella *sp.*?, r
Uncinulus campbellanus *Hall*, c
Spirifer perlamellosus *Hall*, r

Becraft limestone

This prominent formation with a thickness of about 40 feet, consists of massive beds of light gray, white and pink semicrystalline shell limestone of high purity. It is virtually a consolidated coquina, made up chiefly of fragments of brachiopod shells and crinoids. It is hard and solid and for this reason its

organic remains, which are exceedingly abundant, can be collected only with great difficulty. The lower portion of the Becraft is a bluish gray limestone traversed by many thin shale films which intersect the main bedding planes at small angles. The middle portion of the Becraft is a massive bed of hard light gray, white or pink crystalline limestone, 18 to 20 feet thick, made up entirely of organic remains, and running from 94 to 97% of lime carbonate.

It is very homogeneous throughout and is accordingly one of the most resistant members of the series, and has suffered a smaller amount of deformation; though it is faulted and folded in considerable degree, it has no slaty cleavage. Both the upper and lower portions of the Becraft are of darker color and are traversed by thin shale films. These shale films seem to have afforded lines of weakness along which movements due to lateral compression have taken place, and these portions of the Becraft are accordingly more broken up than is the middle.

The lower dark gray Becraft constitutes a series of limestone beds 10+feet thick which graduate nicely into the thinner layers of limestone forming the subjacent New Scotland beds. There is however a well marked division plane between the two formations.

The upper Becraft, 6+feet thick, of somewhat darker gray limestone, traversed by films of darker shale, anticipates the conditions seen in the next overlying formation, the Port Ewen beds, and its upper limit is marked by a prominent division plane. The entire formation is replete with fossils, but the fauna has not yet been well worked out. At a few favorable points fairly good silicified fossils have been collected, but as a rule diagenesis within the limestone sediments has rendered the organic remains so indistinct that the majority of them can not be identified.

This limestone is of considerable economic importance and has been largely quarried in this vicinity, as well as to the southward and northward from here, for the high grade of lime which it produces when burned. The lighter colored white or pink middle ledge furnishes the best lime. The vertical cut on the west side of the Vlightberg, Gross's quarry on Delaware avenue, and

the White lime quarry, Old quarry, and Cloonan's quarry extend along the strike of the formation northward. There are also extensive quarries in the edge of the Becraft on the hill between Port Ewen station on the West Shore Railroad and the Wilbur bridge over Rondout creek, and the transition from the New Scotland to the Becraft can be well studied on the hillside over the southeast portal of the West Shore tunnel, about 2 miles south from the Vlightberg.

At a few points the Becraft limestone forms ridges of low relief, as is generally the case with such massive pure limestones, but it has as a rule suffered extensive denudation by solution and it occupies the hollows or lies under the lee of protecting ledges of the Port Ewen beds. On the North hill there are two " veins " of the Becraft, one in its normal position near the eastern edge of the hill, the second on the overthrust block, running parallel to the first vein and from 700 to 1100 feet west of it.

FAUNA OF THE BECRAFT LIMESTONE

Middle portion

Aspidocrinus scutelliformis *Hall*, aa
Spirifer concinnus *Hall*, aa
Atrypa reticularis *Linne*, c
Lichenalia *sp.*?, c
Meristella *sp.*?, c
Rhipidomella oblata *Hall*, c
Gypidula pseudogaleata *Hall*, a
Rensselaeria aequiradiata (*Conrad*), c
Uncinulus nobilis *Hall*, c
U. campbellanus (*Hall*), aa
Stropheodonta becki *Hall*, a
Rhynchotrema formosum *Hall*, r
Rhynchonella transversa *Hall*, c
Schizophoria multistriata *Hall*, c
Phacops logani *Hall*, r
Stropheodonta *cf.* varistriata (*Conrad*), c

FAUNA OF THE UPPER BECRAFT

Silicified fossils in clay

Gypidula pseudogaleata *Hall*, a
Atrypa reticularis *Linne*, a
Spirifer concinnus *Hall*, a
Rhipidomella oblata *Hall*, c
Crinoid fragments, a
Stropheodonta arata *Hall*, r
Leptaena rhomboidalis (*Wilck*), c
Nucleospira ventricosa *Hall*, c
Spirifer perlamellosus *Hall*, c
Oriskania (?) *sp.*?, r

Port Ewen limestone

Above the Becraft limestone is a formation which, because of its influence on the topography of the vicinity, is one of the most important of the series. It was first noted by Davis [1883, p. 390][1], who called it the " Upper Shaly limestone " in contradistinction to the " Lower " or " Catskill Shaly limestone," now

[1] *See* Works mentioned in the text, p. 1227.

the New Scotland beds. Davis does not cite any particular locality where this formation can be seen, but this map [op. cit. p. 391] shows the formation, as understood by him, to be present in all continuous sections in the vicinity of the Vlightberg, the North hill, the Port Ewen section, and in what he calls "the southwestern synclinal," which extends southward for about 2 miles from the village of Wilbur along the western side of Rondout creek. Darton [1894, p. 303, 318, map and sections on pl. 4, p. 319-25] describes the occurrence and relations of this formation in the vicinity of Rondout and southward toward Rosendale. At a later date, with the object of eliminating physical terms of nomenclature, Clarke and Schuchert [1899, p. 878] applied the name "Kingston beds" to this formation, and cited as typical the section seen along the West Shore Railroad southeast of the high bridge over the Rondout creek about 1½ miles south of the Kingston depot, which had been examined by van Ingen and Ruedemann [Clarke, 1900, p. 73]. The term "Kingston" was however preoccupied and accordingly Clarke [1902, p. 666] suggests the name Port Ewen, taking it from the name of the West Shore station near which the formation is seen to best advantage.

The Port Ewen beds lie between the Becraft limestone and the Oriskany sandstone and they consist of massive beds of impure siliceo-argillaceous limestones which slightly resemble the New Scotland limestones that lie below the Becraft. The minimum thickness, as determined by careful measurements at different points in the vicinity of Rondout, varies from 110 to 160 feet, and the formation probably attains, in places, a maximum thickness of about 200 feet. The peculiar characteristics of these Port Ewen beds are best seen in the cuts along the West Shore Railroad between Port Ewen station and the southeast end of the high bridge at Wilbur, and in the prospect tunnel driven into the hanging wall of the White lime quarry on the North hill. Other favorable points for examining the formation are: on the hillside over the southeast end of the West Shore Railroad tunnel at Wilbur, where the entire formation is seen lying between the Becraft below and the Oriskany above; on the top of the quarry in the Becraft limestone along the curved outcrop of the synclinal trough southwest of the Port Ewen railway cut; in the

hillside on the north side of Delaware avenue between Gross's residence and Gross's quarry; and in the vicinity of Whiteport on the Walkill Valley Railroad, about 5 miles south of Kingston. Two sections can be seen at Whiteport: one near the railway station shows the Port Ewen beds underlying the Oriskany sandstone; the other section in the bluff on the east side of the track about 1 mile south of Whiteport station, shows the Port Ewen beds, 180 feet thick, outcropping at the top of the bluff between the Becraft and Oriskany.

The fresh rock of this formation can best be obtained in the prospect tunnel of the White lime quarry, which with a length of 152 feet has penetrated a thickness of 107 feet of the Port Ewen beds without reaching the chert near the top of the formation. It is hard dark gray, evenly fine grained siliceo-argillaceous limestone of very uneven fracture, containing a considerable amount of finely disseminated iron pyrites, which hastens the decomposition of the rock. One of the most characteristic features of this formation and one which renders it easily recognizable from a distance, and which is best observed in the railway cuts and on the hillside near the tunnel at the Wilbur bridge, is the presence throughout the greater part of the formation of well marked concretionary nodules of purer limestone, which lie in lines parallel to the bedding planes of the rock. The fresh rock of the nodules is slightly lighter in color and it weathers by solution of its lime content much more rapidly than does the general mass of the formation. The residual material is a yellowish brown sandy mud rock or "rotten stone" which is easily carried off during rain storms, so that lines of cavities are formed in the exposed edges of the formation. These pockets of rotten stone often contain well preserved silicified fossils. With exception of the lowermost portion of the formation, which, through a thickness of 10 or 12 feet just above the Becraft, consists of lighter colored, more fossiliferous, purer limestone, the general mass of the Port Ewen beds is not prolific of organic remains. They can not be obtained at all from the fresh rock (except in the basal layers), but careful search of the weathered surfaces and specially of the rotten stone pockets, will yield a considerable amount of satisfactory material in the form of

molds and casts. Such material formed the basis of the list of species given by Clarke in his description of the section along the West Shore tracks near Port Ewen station [1900, p. 73].

A certain superficial resemblance exists between the Port Ewen and the New Scotland beds, and as this resemblance may lead, and indeed has led, to confusion on the part of students and others who make hurried visits to the region, it may be well to describe some of the characters by which the two formations may be distinguished.

The New Scotland beds are alternating series of bands of shale and limestone, with lines or seams of nodular chert in the lower portion, and the entire series is replete with organic remains. The basal New Scotland is a shaly, blue gray limestone, abounding in the shells of Gypidula galeata. The upper portion of the New Scotland gradually changes from a dark gray shaly limestone to a bluish gray limestone, and finally merges into the heavy beds of the Becraft through gradual increase in the thickness of the purer limestone seams and a corresponding diminution of the shale content of the mass. The Port Ewen beds, on the other hand, commence with an impure limestone, without chert, little different from the upper part of the Becraft, which by increase in frequency and thickness of the undulating seams of yellowish shaly material, and corresponding loss or diminution of the lime seams, assumes within 20 feet above the top of the Becraft the typical character of the Port Ewen beds. This typical character is that of massive dark gray, impure limestone that weathers brown and that contains lines of nodules of purer limestone which form cavities in the weathered rock surfaces. Toward the top of the Port Ewen beds the rock changes from the even grained dark limestone, which persists through a thickness of about 100 feet, and seams of black chert become intercalated in the layers of limestone. These chert layers increase in thickness, the limestone diminishes in thickness, and finally layers of pebbles appear to indicate the proximity of the overlying Oriskany sandstone. The chert layers, aggregating 11 feet, 3 inches, in the Port Ewen section, and of slightly greater thickness toward the south near Whiteport, seem to mark the upper part of the Port Ewen beds at all points where this formation

has been observed. The lowermost beds of black chert at the base of the Oriskany seen in the east bank of Esopus creek just below the iron bridge where the Mt Marion to Glasco turnpike crosses the creek below Glenerie, about 7 miles north of Kingston, are considered to represent the chert beds of the upper part of the Port Ewen formation, though the characteristic Port Ewen limestone beds have not yet been recognized in the vicinity of Glenerie. Another point of difference between the New Scotland and the Port Ewen is relative scarcity of fossils of the latter formation.

Both Davis and Darton emphasize the prominence of the slaty cleavage of the "Upper Shaly" beds. Our observations in various parts of the region have demonstrated that cleavage is far more prominently developed in the New Scotland than in the Port Ewen beds. This would be expected as the New Scotland limestones and shales are much the softer and less resistant beds.

The fauna of the Port Ewen beds is strictly Helderbergian in its expression, no true Oriskany species have yet been found in it, though many of its members are also found in the Oriskany fauna. The list published by Clarke [1900, p. 73] contains the names of species found in the various layers of the formation exposed in the Port Ewen railroad cut. New material obtained from the lower part of the formation along the edge of the hanging wall of the White lime quarry affords the following list of species.

FAUNA OF THE LOWERMOST PORT EWEN BEDS

In edge of hanging wall of White lime quarry

This horizon is the same as that of bed 4 of the railroad cut section published by Clarke [1900, p. 73].

Leptaena rhomboidalis (*Wilck*), c
Atrypa reticularis *Linne*, a. Some very old individuals with thickened anterior margins of shell
Strophonella leavenworthana *Hall*, c
Dalmanella perelegans *Hall*, c
Orthothetes woolworthanus (*Hall*), c
Spirifer perlamellosus *Hall*, c
Rhipidomella oblata *Hall*, c
Meristella laevis (*Vanuxem*), c
Uncinulus campbellanus (*Hall*), c
Nucleospira elegans *Hall*, r
Phacops logani *Hall*, c
Chaetetes *sp.*?, c
Hindia fibrosa (*Roemer*), c
Tentaculites elongatus *Hall*, c
Anastrophia *cf.* verneuilli (*Hall*)
Spirifer concinnus *Hall*, c
Acidaspis tuberculatus *Hall*, c

Oriskany beds

The Oriskany of this vicinity presents two distinct kinds of deposits. The lower portion is a pebble bed or conglomerate 6 to 18 feet thick; the upper portion, 20 to 50 feet in thickness, consists of layers of sandy limestones intercalated with bands of cherty limestone, both of which are replete with fossils.

The difference between the typical Port Ewen and the pebbly Oriskany is very great though the change from the one formation to the other was not violent, as indicated by the following detailed section measured on the West Shore Railroad cut about ¼ mile south of the Wilbur bridge. The beds are numbered in ascending order.

	Feet	Inches
14-21 Typical Port Ewen nodular limestone....	66	2
22 Band of black chert..........................	1	6
23 Impure limestone with much chert in thin bands; no fossils..........................	4	9
24 Black, banded chert with thin limy bands. The limestone bands contain a small amount of quartz sand	5	0
25a Layer of quartz pebbles of size of peas.....	0	3
25b Black chert	0	9
26 Alternating thin bands of pebbles and chert..	3	7
27 White pebble bed	5	0
A solid bed of well rounded, waterworn, white quartz pebbles, of size varying from peas to white beans, stained with brown iron oxid, cemented by limestone in some parts, elsewhere no cement and pebbles loose. Fossils consisting of waterworn fragments of the larger Oriskany brachiopods and gastropods.		
28 Black pebble bed	9	0

This is a solid bed of white rounded quartz pebbles of about the same size as those of bed 27, but in places attaining even 1 inch in diameter. These are embedded in a tough hard matrix of dark siliceous mud cement, that often assumes the character of black chert. Among the quartz pebbles are often pebbles of black chert like that of beds 22, 24, 25b; and a few masses of

concretionary appearance consist of white quartz pebbles in black chert cement. The cement matrix is rarely calcareous, so that this rock resists erosion and decomposition better than other members of the series. Throughout the bed are scattered, sometimes abundantly, much waterworn fragments of Oriskany shells.

29-34 Sharp on the top of the black pebble bed lies a series of siliceous and sandy limestones in thin layers of 4 to 12 inches thickness, which when fresh are very hard and of black or dark gray color, but which when weathered turn into a soft brown rotten stone. These beds with a thickness of 42 feet in this section, constitute the highly fossiliferous Oriskany which has yielded such finely preserved silicified fossils, and of which the upper layers are absent in this section. The entire thickness of this upper portion of the formation approximates 50 feet, in this immediate vicinity.

North of Rondout the thickness of the Oriskany diminishes to about 20 feet at Glenerie. Darton's figures of the thickness of this formation [1894, p. 497] can not be depended on. In the Rondout region, where Darton says it is "30 feet, including the conglomeratic member," we find it to be at least 60 feet, with the upper portion removed by erosion. A carefully measured section of the Oriskany, including the pebble bed at the base, but without the top layers which here also have been removed by erosion, along the railway at Whiteport station, shows 70 feet, 6 inches of this formation, while Darton [op. cit., p. 497] states "In the Whiteport region and southward the formation consists of a silicious limestone bed which has a thickness of from 8 to 9 feet." On the top of the hill 1 mile south of Whiteport station, the total thickness of the Oriskany is about 80 feet. Ries, in his *Report on the Geology of Orange County N. Y.* (N. Y. State Geol. 15th An. Rep't. 1897. 1:402), gives the Oriskany in the vicinity of the Neversink valley north of Port Jervis a thickness of 125 feet. This thickness increases to the southward, as noted by Weller [1903, Geological Survey of New Jersey, Report on Paleontology, 3:93] who quotes 170 feet for the Oriskany in the Walpack ridge a few miles south of Port Jervis. The Oriskany of New Jersey contains a fauna, that of the

Dalmanites dentatus zone, which is apparently older than any so far recognized in the Oriskany of New York. This "dentatus fauna" comprises, according to Weller, in addition to a number of Lower Helderberg species and species peculiar to itself, the following Oriskany types: Stropheodonta magnifica, Spirifer murchisoni, Cyrtina rostrata and Orbiculoidea ampla. It seems to occupy a horizon corresponding to the upper part, possibly to the black cherts, of the Port Ewen beds of the Rondout and Whiteport sections.

The limit between the Port Ewen and the Oriskany has been drawn by us at the bottom of layer 27, the white pebble bed which marks the commencement of new and peculiar conditions of sedimentation and life of Oriskany time. That the pebble beds owe their origin to currents of considerable strength seems evident from the nature of the fragments of which they are composed. The pebbles themselves are in all respects small copies of the rolled white quartz pebbles that compose the massive Shawangunk grit, and their source is perhaps to be sought for in masses of this latter formation, which, during that early Devonic time, projected above sea level in the vicinity of what are now the Shawangunk mountains along the eastern shore of the mediterranean basin or trough in which the Helderbergian and Oriskanian sediments were being deposited. No unconformity can be distinguished between the Port Ewen and Oriskany, though small rolled fragments referable to the Port Ewen black chert occur frequently in the Oriskany beds.

The Oriskany pebble beds are well exposed in the small ridge just west of Gross's residence; farther to the north they are seen along the western slope of the North hill where they are overlain by the upper sandy and cherty limestones of the same formation. Another excellent exposure, where the loose gravellike character of the lower pebble bed is well shown, is along Abeel street that runs from Rondout south along the left bank of the Rondout creek at a point near the old coal docks and about ¼ mile north of the South Rondout ferry.

The pebble beds are quite constant throughout the southern part of the Little Mountain belt, and they are recorded by Davis

and Darton as occurring, with diminishing thickness, to the northward as far as Catskill creek. No such clear quartz sandstone as that of the classical Oriskany localities of Union Springs, Oriskany Falls and Schoharie, has yet been found in the Little Mountain belt. To the southward the pebble beds have been noted as far as Rosendale, and there is no evidence that they do not extend beyond that point. They are not, however, mentioned by Ries from Orange county, and in Weller's Walpack ridge section in New Jersey, there is a hiatus at the horizon where they might be expected to occur.

The upper sandy and cherty beds of the Oriskany are filled with fossils, and at many points, specially where the beds have slightly inclined attitudes permitting the surface waters containing vegetable acids to seep through the joint cracks and dissolve the calcareous cement, pockets of residual sandy mud contain abundant, exquisitely preserved, silicified fossils, that rival and often surpass the noted specimens from Cumberland Md. The best collecting grounds for this material are: in the West Shore Railroad cut between Port Ewen and the Wilbur bridge; on the Walkill Valley Railroad at Whiteport; along the western slope of the North hill at Rondout, beginning a short distance north of Gross's house and extending to and beyond Terry triangulation station. But by far the best locality and one from which in the past the senior author has obtained large and fine collections (now in the possession of Dr John M. Clarke of Albany, and Prof. H. S. Williams of Yale University) is along the right bank of Esopus creek between the Glenerie lead mills and the iron bridge on the Mt Marion to Glasco road. This locality is about 7 miles north of Kingston, and 1½ miles east of Mt Marion station on the West Shore Railroad. Here the beds are exposed, dipping about 15° to the westward, in broad areas along the roadside and the bank of the creek, and search in the decomposed material along the joint cracks has brought to light a wealth of fossils, in a state of preservation unequaled elsewhere in New York State. The fauna obtained there, of which an incomplete list is given, comprises upward of 125 species, a large number for a single bed at a single locality.

Several of the species mentioned in the Glenerie list have been found in the various other localities about Rondout, but no record has been made of them.

This Glenerie fauna is quite as large as that of the Becraft mountain Oriskany, described by Clarke [1900], but differs from it in some important respects, of which the most notable is the larger proportion of New Scotland species present in the Glenerie beds. No comparison can yet be made between the pelecypods and bryozoans of the two faunas, as these organisms in the Glenerie collections have not been identified.

The large percentage of New Scotland species (26 out of a total of 94) in the Glenerie Oriskany emphasizes the close affinities between the Helderbergian and Oriskanian faunas. Indeed the Glenerie fauna and the beds containing it present essentially a recurrence of the conditions of sedimentation and of the fauna of the New Scotland beds during Oriskany time. The true Oriskany element of the Glenerie fauna (represented by such species as Edriocrinus sacculus, Rhipidomella musculosa, Leptaena ventricosa, Leptostrophia magnifica and L. magniventer, Hipparionyx proximus, the large Camarotoechias, Spirifer arenosus and S. murchisoni, Rensselaeria ovoides, Megalanteris ovalis, Beachia suessana, Actinopteria arenaria, etc.) is considered by us to have been derived by migration from a contemporaneous fauna which occupied an adjoining basin or trough farther to the westward, under somewhat different bionomic conditions. Instead of considering the eastern calcareous beds as Lower and the western arenaceous beds of the Hipparionyx fauna as Upper Oriskany, as suggested by Schuchert, we are disposed to follow Clarke in regarding these two types as presenting two distinct contemporaneous facies of the Oriskany. At no point have these two facies with their distinct faunas been found superimposed in a single section, nor have they been found in close proximity to each other. We do not include in this suggestion of contemporaneity the Oriskany-Onondaga fauna of Ontario, Canada, which is undoubtedly of later age. The pres-

ence of the genus Ambocoelia, and of the fish spine, Machaeracanthus sulcatus, both Devonian types, in the Glenerie fauna is noteworthy in this connection.

GLENERIE ORISKANY FAUNA

a=abundant c=common r=rare

Species marked (N) are New Scotland species; (O) are typical Oriskany species of central New York province; (D) are Onondaga limestone types. (C) indicates Cumberland Md., species.

Chaetetes sphaericus *Hall*, (N), a
Aulopora *sp.*?
Pleurodictyum lenticulare *Hall*, (N), r
Hindia fibrosa *Roemer*, (N), r
Edriocrinus sacculus *Hall*, (O), c
Fenestella *sp.*?
Orbiculoidea jervensis *Barrett*, r
Pholidops terminalis *Hall*, (C), a
P. ovata *Hall*, (N), c
Rhipidomella oblata *Hall*, (N), c
R. emarginata *Hall*, (Lower Helderberg, Cumberland Md.), r
R. musculosa *Hall*, (O) (C), a
R. discus *Hall*, (N), r
Dalmanella perelegans *Hall*, (N), c
D. planoconvexa *Hall*, (*N*), a
Leptaena rhomboidalis *Wilckens*, (N), r
L. ventricosa *Hall*, (O), a
Brachyprion schuchertanum *Clarke*, c
B. majus *Clarke*, c
Leptostrophia becki *Hall*, (N), c
L. magnifica *Hall*, (O), a
L. magniventer *Hall*, (O), a
L. oriskania *Clarke*, c
Stropheodonta lincklaeni *Hall*, (O), r
Orthothetes becraftensis *Clarke*, a
O. woolworthanus *Hall*, (*N*), c
Hipparionyx proximus *Vanuxem*, (O), c
Chonostrophia complanata *Hall*, (O), c
Chonetes hudsonicus *Clarke*, c
Anoplia nucleata *Hall*, (O), a
Anastrophia verneuilli *Hall*, (N), r
Camarotoechia pliopleura *Hall*, (O), c
C. fitchiana *Hall*, (O), c
C. oblata *Hall*, (O), a
C. multistriata *Hall*, r
Eatonia peculiaris *Conrad*, (O), a
E. singularis *Hall*, (N), r
E. whitfieldi *Hall*, (C), r
E. medialis *Hall*, (*N*), r
Coelospira dichotoma *Hall*, (C), a
C. concava *Hall* (1867), (O), c
Leptocoelia flabellites *Conrad*, (O), a
L. acutiplicata *Conrad*, (D), c
Cyrtina rostrata *Hall*, (O), a
C. dalmani *Hall*, (N), r
Spirifer arenosus *Conrad*, (O), c
S. murchisoni *Castelnau*, (O), a
S. tribulis *Hall*, (C), a
S. cyclopterus *Hall*, (*N*), a
S. saffordi *Hall*, a
S. modestus *Hall*, (C), c
Metaplasia pyxidata *Hall*, (O), c
Ambocoelia *sp. nov.*, c
Meristella lentiformis *Clarke*, c
M. lata *Hall*, (O), c
M. vascularia *Clarke*, r
Nucleospira ventricosa *Hall*, (*N*), c
N. elegans *Hall*, (N), r
Trematospira multistriata *Hall*, (N), r
T. costata *Hall*, (N), r
T. *sp. nov.*, large
Parazyga deweyi *Hall*, (N), c
Rhynchotrema formosum *Hall*, (*N*), r
Oriskania navicella *Hall & Clarke*, c
O. sinuata *Clarke*, r
Cryptonella fausta *Clarke*, r
Megalanteris ovalis *Hall*, (O), c
Beachia suessana *Hall*, (C), c
Rensselaeria ovoides *Eaton*, (O), c
Pterinopecten proteus *Clarke*
Actinopteria arenaria *Hall*, (O), c
Aviculopecten rectirostra *Hall*, (O), r
Megambonia crenistria *Clarke*, r
Spirorbis assimilis *Clarke*, r
Tentaculites elongatus *Hall*, (O), c
Cyrtolites expansus *Hall*, (O), r
C. *sp. nov.*, r

Diaphorostoma desmatum *Clarke,* c
D. ventricosum *Conrad,* (N), a
Strophostylus expansus *Conrad,* (O)
Orthonychia tortuosa *Hall,* (O)
Platyceras gebhardi *Hall,* (C), c
P. nodosum *Conrad,* (O), a
P. reflexum *Hall,* (C), c
P. pernodosum *sp. nov.,* r
P. platystomum *Hall,* (N), r
P. lamellosum *Hall,* (N), r
Orthoceras *sp.?,* r
Ostracoda, several minute species unident.
? Cirripede, of Balanoid type
Phacops logani *Hall,* (*N*), r
Dalmanites pleuroptyx *Green,* (N), c
D. stemmatus *Clarke,* c
Homalonotus major *Whitfield,* r
Machaeracanthus sulcatus *Newberry,* (D), r
Spirophyton cauda galli *Vanuxem* (D), c

Esopus grit

This thick formation covers large areas of country to the west of the Vlightberg and the North hill at Rondout, and it forms the crests of most of the hills along the roads leading from Kingston southwest to Rosendale. Its thickness is 300 to 325 feet. It is a heavy bedded, soft, argillaceous grit of dark olive-brown color and of remarkably even grain throughout its mass, and it is quite barren of organic remains. It has well developed slaty cleavage, which often obscures the deposition planes of the rock, and on its weathered surfaces it breaks down into rounded hillocks covered with small angular fragments of the stone. Its lower beds are quite heavy, somewhat harder in texture, and their bedding planes are covered with the fucoid Spirophyton caudagalli Vanuxem.

The formation can be well seen in the high bluffs overlooking the left bank of the Rondout creek just north of the Wilbur bridge, and also in the cuts of the West Shore Railroad between the Wilbur tunnel and the Wiltwyck cemetery. It is also finely exposed in the left bank of the Esopus creek at Glenerie its type locality.

Its upper layers become more limy and finally, through gradual changes they merge into the argillaceous limestones of the lower portion of the Onondaga beds. This transition can be well seen in the West Shore Railroad cuts south of Kingston station, and in the banks of Esopus creek beneath the West Shore bridge at the Glenerie falls.

The only fossils found in this formation are Leptocoelia acutiplicata, Atrypa spinosa, an obscure Discinoid brachiopod and Spirophyton caudagalli.

Onondaga limestone

This formation is not found on either the Vlightberg or North hill, but as it is one of the most important members of the series in the Kingston region, a few words are devoted to its characteristics. The upper part of the Esopus grit merges into the lower portion of the Onondaga by such gradual changes that no line of demarcation can be drawn. These lower impure limestones are about 40 feet in thickness, and they are overlain by about 30 feet of purer blue gray, hard silicious limestone that lies in beds of from 1 to 5 feet thick. The upper portion of the pure limestone carries considerable black chert that projects as irregular knobs on the weathered surfaces of the rock. This formation abounds in fossils, but the rock is so hard and splintery that they are very difficult to extract. Atrypa reticularis, Leptostrophia perplana, Platyceras dumosum, Leptaena rhomboidalis, are the most common species.

The Onondaga limestone is well exposed along the West Shore Railroad between the Wiltwyck cemetery and the tunnel; several quarries have been opened into it within the Kingston city limits; and it is also finely exposed along the western slope of the monoclinal ridge that parallels the east side of the West Shore Railroad for several miles north of Kingston, specially in the vicinities of Lake Katrine, Glenerie falls, Mt Marion and Saugerties.

Range of the Helderbergian and Oriskanian species

The following table shows the range of the various species of fossil organisms throughout the members of the Helderbergian and Oriskanian series in the Rondout region. The table is based on the lists already given in the text above; and Clarke's list of the Port Ewen fauna, published in his Becraft memoir [1900, p.73], has been incorporated. The relative abundance of the species is indicated by letters: a=abundant, c=common, r=rare, v=present.

	Lower Coeymans	Middle Coeymans	Upper Coeymans	Lower New Scotland	Middle New Scotland	Upper New Scotland	Lower Becraft	Middle Becraft	Upper Becraft	Lower Port Ewen	Upper Port Ewen	Oriskany at Rondout	Oriskany at Glenerie	Esopus grit
Hindia fibrosa *Roemer*		a	c	c						c			r	
Sponge, *gen. et sp.?*		r												
Aulopora *sp.?*													v	
Chaetetes sphaericus *Hall*	c		v	c	c								a	
C. *sp*										c				
Duncanella rudis *Girty*										v	c			
Favosites helderbergiae *Hall*	c	c												
Pleurodictyum lenticulare *Hall*										v	v		r	
Zaphrentis roemeri *E. & H.*										v				
Aspidocrinus scutelliformis *Hall*						a	a	a	a					
Edriocrinus sacculus *Hall*												v	c	
Fenestella *sp.?*													v	
Lichenalia torta *Hall*	a	c	r	c	c									
L. *sp.?*								c						
Cladopora smicra *Clarke*												v		
Orbiculoidea jervensis *Barrett*													r	
Pholidops ovatus *Hall*											c		c	
P. terminalis *Hall*													a	
Pholidops *sp.?*	r				r									
Bilobites varicus *Conrad*			c											
Dalmanella perelegans *Hall*		c	c	c	c					c			c	
D. planoconvexa *Hall*											v		a	
D. subcarinata *Hall*	r									v				
Rhipidomella discus *Hall*					r								r	
R. emarginata *Hall*	v												r	
R. musculosa *Hall*													a	
R. oblata *Hall*	c			c		c		c	c	c	v		c	
R. *small species*			c											
Schizophoria multistriata *Hall*								c						
Leptaena rhomboidalis *Wilck*	c		c	a	a				c	c			r	
L. ventricosa *Hall*													a	
Leptaenisca concava *Hall* ?			r											
Stropheodonta arata *Hall*					c				r					
S. becki *Hall*	r			a	c	c		a		v	v		c	
S. lincklaeni *Hall*													r	
Stropheodonta *cf.* planulata *Hall*	r													
S. varistriata *Conrad*	c		c											
Stropheodonta *cf.* varistriata *Conrad*								c						
Brachyprion schuchertanum *Clarke*													c	
B. majus *Clarke*													c	
Leptostrophia magnifica *Hall*													a	
L. magniventer *Hall*													a	
L. oriskania *Clarke*												v	c	
Strophonella cavumbona *Hall*					c									
S. leavenworthana *Hall*	r									c				
S. punctulifera *Conrad*	c	r	v	c	r					v				
S. radiata *Vanuxem*					a									
Strophonella *sp.?*				v										
Orthothetes becraftensis *Clarke*													a	
O. woolworthanus *Hall*	r			a	a	c				c			c	
O. *sp.?*			r											
Hipparionyx proximus *Vanuxem*													c	
Chonostrophia complanata *Hall*												v	c	
Chonetes hudsonicus *Clarke*												v	c	

	Lower Coeymans	Middle Coeymans	Upper Coeymans	Lower New Scotland	Middle New Scotland	Upper New Scotland	Lower Becraft	Middle Becraft	Upper Becraft	Lower Port Ewen	Upper Port Ewen	Oriskany at Rondout	Oriskany at Glenerie	Esopus grit
C. *sp.?*	..	..	..	..	r	..	..	..	..	..	..	..	..	..
Anoplia nucleata *Hall*	..	..	..	..	r	..	..	..	..	..	..	..	a	..
Gypidula galeata *Dalman*	c	c	a	..	..	..	..	..	..	..	..	..	..	..
" large var.	..	c	..	..	..	..	..	..	..	..	..	..	..	..
G. pseudogaleata *Hall*	..	..	..	..	..	r	..	a	a	..	..	..	..	..
Anastrophia verneuili *Hall*	..	r	..	..	..	..	..	..	..	?	..	..	r	..
Rhynchonella bialveata *Hall*	..	..	..	..	r	..	..	..	..	..	..	..	..	..
R. inutilis *Hall*	..	..	..	..	r	..	..	..	..	..	..	..	..	..
R. semiplicata *Conrad*	c	..	..	..	..	..	..	..	..	..	..	..	..	..
R. transversa *Hall*	..	..	..	..	..	a	..	c	..	..	..	..	..	..
Uncinulus campbellanus *Hall*	..	..	..	..	..	c	..	a	..	c	..	..	..	..
U. mutabilis *Hall*	c	..	..	..	..	..	..	..	..	v	..	..	..	..
U. nobilis *Hall*	..	..	..	..	..	..	..	c	..	..	..	..	..	..
U. nucleolatus *Hall*	..	c	c	..	..	..	..	..	..	..	..	..	..	..
Uncinulus vellicatus *Hall*	..	..	..	..	r	..	..	..	..	..	..	..	..	..
Rhynchospira formosum *Hall*	r	..	..	..	..	a	..	r	..	..	..	..	r	..
Camarotoechia fitchana *Hall*	..	..	..	..	..	..	..	..	..	..	..	..	c	..
C. multistriata *Hall*	..	..	..	..	..	..	..	..	..	..	..	..	r	..
C. oblata *Hall*	..	..	..	..	..	..	..	..	..	..	..	..	a	..
C. pliopleura *Hall*	..	..	..	..	..	..	..	..	..	..	..	v	c	..
C. barrandii *Hall*	..	..	..	..	..	..	..	..	..	..	..	v	..	..
Eatonia medialis *Vanuxem*	..	..	..	c	c	..	..	..	..	v	v	..	r	..
E. peculiaris *Conrad*	..	..	..	c	..	..	..	..	..	v	v	v	a	..
E. singularis *Hall*	..	..	..	..	..	..	..	..	..	..	..	..	r	..
E. whitfieldi *Hall*	..	..	..	..	..	..	..	..	..	..	..	..	r	..
Spirifer arenosus *Conrad*	..	..	..	..	..	..	..	..	..	..	..	..	c	..
S. concinnus *Hall*	c	..	..	..	..	c	..	a	a	c	..	..	..	..
S. cyclopterus *Hall*	c	..	r	c	..	a	..	..	..	v	v	..	a	..
S. macropleurus *Conrad*	r	..	..	c	..	..	..	..	..	..	..	..	..	..
S. modestus *Hall*	..	..	..	..	..	..	..	..	..	..	v	..	c	..
S. murchisoni *Castelnau*	..	..	..	..	..	..	..	..	..	..	..	v	a	..
Spirifer *cf.* octocostatus *Hall*	..	..	v	..	..	..	..	..	..	..	..	..	..	..
S. perlamellosus *Hall*	r	..	v	c	c	r	..	..	c	c	..	..	..	..
S. saffordi *Hall*	..	..	..	..	..	..	..	..	..	..	..	..	a	..
S. tribulis *Hall*	..	..	..	..	..	..	..	..	..	..	..	..	a	..
Cyrtina dalmani *Hall*	r	..	..	..	..	..	..	..	..	..	..	..	r	..
C. rostrata *Hall*	..	..	..	..	..	..	..	..	..	..	..	..	a	..
Ambocoelia *sp. nov*	..	..	..	..	..	..	..	..	..	..	..	..	c	..
Metaplasia pyxidata *Hall*	..	..	..	..	..	..	..	..	..	..	..	..	c	..
Trematospira costata *Hall*	..	..	..	..	..	..	..	..	..	..	..	..	r	..
T. multistriata *Hall*	..	..	..	..	..	..	..	..	..	..	..	..	r	..
T. *sp. nov.* large	..	..	..	..	..	..	..	..	..	..	..	..	r	..
Rhynchospira globosa *Hall*	r	..	r	..	..	..	..	..	..	..	..	..	..	..
R. *sp. nov*	c	..	..	..	..	..	..	..	..	..	..	..	..	..
Parazyga deweyi *Hall*	..	..	r	..	..	..	..	..	..	..	..	..	c	..
Nucleospira elegans *Hall*	..	..	..	..	..	..	..	..	..	r	..	..	r	..
N. ventricosa *Hall*	..	..	r	..	..	..	..	..	c	..	..	..	c	..
Nucleospira *sp.?*	r	..	..	..	..	..	..	..	..	..	..	..	..	..
Atrypa reticularis *Linne*	r	a	a	..	..	c	..	c	a	a	..	..	..	..
A. spinosa *Hall*	..	..	..	..	..	..	..	..	..	..	..	..	..	r
Atrypina imbricata *Hall*	..	..	c	c	..	..	..	..	..	..	..	..	..	..
Anoplotheca acutiplicata *Hall*	..	..	..	..	..	..	..	..	..	..	..	..	c	r
A. concava *Hall*	..	..	..	..	c	..	..	..	..	v	v	..	c	..
A. flabellites *Hall*	..	..	..	..	..	..	..	..	..	..	..	v	a	..
Coelospira dichotoma *Hall*	..	..	..	..	..	..	..	..	..	..	..	..	a	..

	Lower Coeymans	Middle Coeymans	Upper Coeymans	Lower New Scotland	Middle New Scotland	Upper New Scotland	Upper Becraft	Middle Becraft	Lower Becraft	Lower Port Ewen	Upper Port Ewen	Oriskany at Rondout	Oriskany at Glenerie	Esopus grit
Meristella laevis *Vanuxem*	r			c						c				
M. lata *Hall*													c	
M. lentiformis *Clarke*												v	c	
M. vascularia *Clarke*													r	
Rensselaeria aequiradiata *Conrad*								c						
R. mutabilis *Hall*						r								
R. ovoides *Eaton*													c	
Beachia suessana *Hall*													c	
Megalanteris ovalis *Hall*												v	c	
Oriskania navicella *Hall & Clarke*													c	
O. sinuata *Clarke*													r	
Oriskania *sp.?*									r					
Cryptonella fausta *Clarke*												v	r	
Actinopteria arenaria *Hall*													c	
A. textilis *Hall*	r	c		c	r	r								
Aviculopecten rectirostra *Hall*													r	
Cypricardinia lamellosa *Hall*											v			
Lamellibranch *gen. & sp. nov*		r												
Megambonia crenistria *Clarke*													r	
M. *sp.?*	c													
Pterinopecten proteus *Clarke*													v	
Cyrtolites expansus *Hall*													r	
C. *sp. nov*												v	r	
Diaphorostoma desmatum *Clarke*												v	c	
D. ventricosum *Conrad*												v	a	
Orthonychia tortuosa *Hall*												v	v	
Platyceras gebhardi *Hall*													c	
P. lamellosum *Hall*													r	
P. nodosum *Conrad*													a	
P. pernodosum *sp. nov*													r	
P. platystoma *Hall*													r	
P. reflexum *Hall*													c	
P. *sp.?*			r											
Platyostoma *sp.?*				r	r									
Strophostylus expansus *Conrad*													v	
Spirorbis assimilis *Clarke*													r	
Tentaculites elongatus *Hall*										c	v	v	c	
Cyrtoceras *small sp.?*					r									
Orthoceras *sp.?*	r												r	
Isochilina *sp.?*				a	c	c							c	
Cirripede?													r	
Acidaspis tuberculata *Conrad*				r	c					c	v			
Bronteus barrandii *Hall*	r													
Dalmanites micrurus *Green*	r	c												
D. pleuroptyx *Green*	c			c	r	r				v	v		c	
D. stemmatus *Clarke*												v	c	
Homalonotus major *Whitfield*													r	
H. vanuxemi *Hall*										v	v			
Phacops logani *Hall*	c			c	r			r		c	v	v	r	
Proetus conradi *Hall*												v		
P. protuberans *Hall*	c			r										
Proetus *sp.?*						r								
Machaeracanthus sulcatus *Newberry*													r	
Spirophyton caudagalli *Vanuxem*													c	a

STRUCTURAL FEATURES

The cross sections on plates 3, 4 and 5 portray the large tectonic features of the Vlightberg and North hill. No attempt has been made to illustrate in these sections the smaller folds and faults which are so numerous in all the quarries and mines. Illustration of these details is reserved for a future paper.

The term "vein" is employed in the Rondout region in a sense similar to that in which it is used in the coal regions, namely for a single layer or for a composite series of layers of sedimentary rock quarried for economic purposes. It has no relation to and should not be confounded with veins of metallic ore deposits.

The compass readings here given have all been reduced to true meridian on the basis of 9°30′ west declination for Rondout.

The unconformity between the Wilbur limestone and the Champlainic sandstone

The Wilbur limestone and the underlying Champlainic sandstone and shale are sharply unconformable at all points in this vicinity where the contact of the two formations can be observed. It can, however, be seen only along the east side of the Vlightberg and in the underground Vlightberg mines. The nature of this unconformity has been well described by Davis;[1] and we can add only a few details to his description. The surface of the tilted sandstones at the unconformity, a surface which represents a very ancient plane (probably Eosiluric) of subaerial degradation, is much more uneven at some points than at others. At the locality marked U near the south end of the Vlightberg, where the unconformity was studied by Davis, and where our photograph [pl. 7] was taken to show the same view illustrated by Davis's sketch [1883. p.392], the eroded edges of the sandstone form a very irregular surface with hollows 6 to 24 inches deep. These hollows are in the nature of grooves parallel to the bedding planes of the rock, and the largest grooves coincide with the most prominent deposition planes, the latter having furnished lines of least resistance for the eroding agent. The hollows are filled with the

[1] 1883. p. 392–93; and 1890. p. 355.

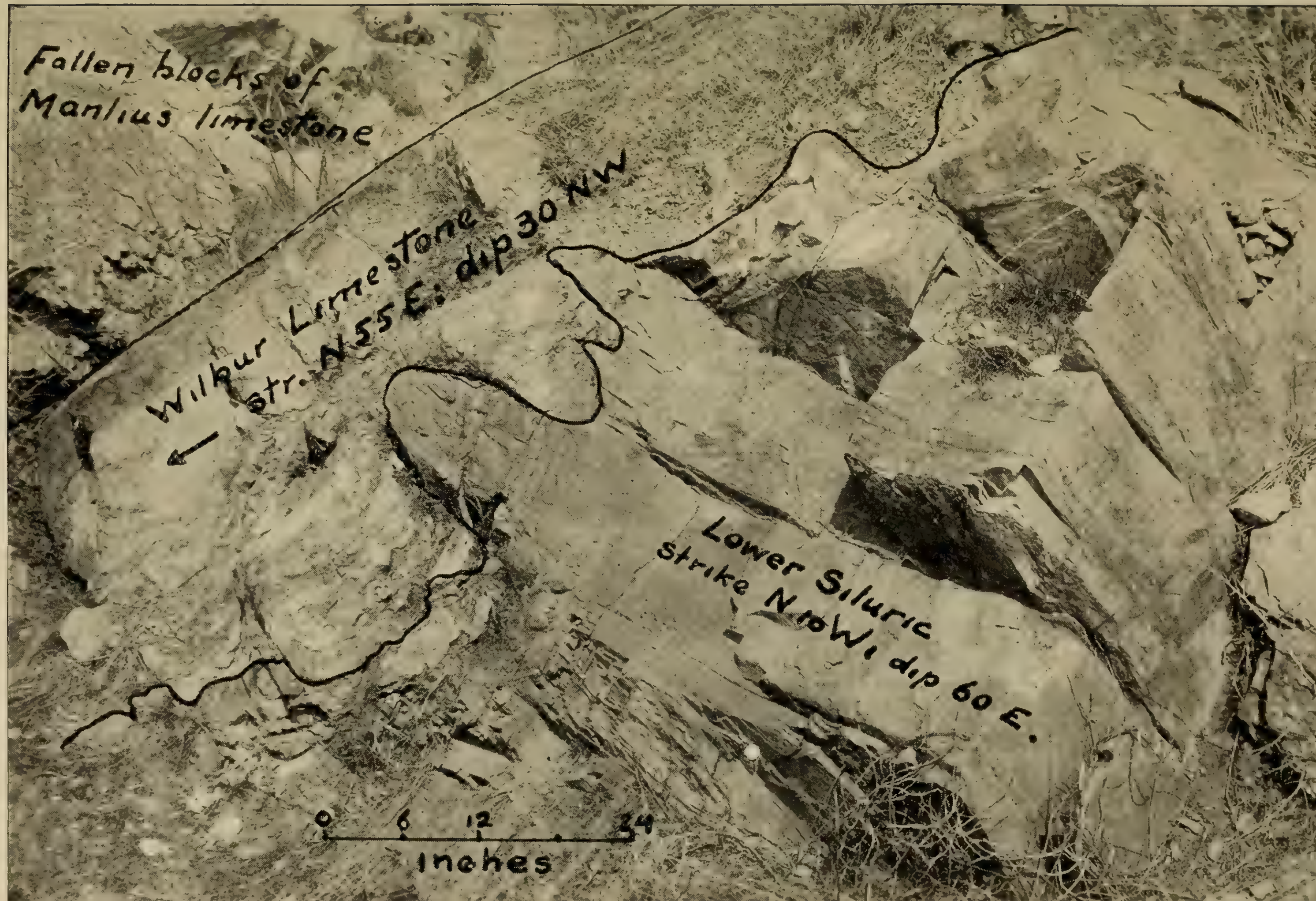
Wilbur limestone, and in the limestone have been found rounded waterworn boulders of sandstone incrusted with fossil bryozoans and corals.

Farther to the northward, at the Hill quarry, the old land surface of the sandstone is quite smooth, but still farther north, in the incline into the North quarry just west of the engine house (E on map, pl. 2), the same surface is again as rough as at the first locality.

The unconformity is expressed not alone by the eroded surface of the Champlainic sandstones, but also by the discordant strikes and dips of the involved formations, which lie at nearly right angles to each other. At the locality U the sandstone strikes n. 10° w. (true meridian) with an easterly dip of 60°; and the Wilbur limestone strikes n. 55° e.; dip 30° n. w. This general attitude of the two formations is maintained at all points where the unconformity has been measured, though there is some variation in the relationship, which can be explained by supposing the dip and strike of the sandstone to have been somewhat variable when the region was submerged beneath the Siluric waters of the Wilbur sea. At the angle of Union street, just south of locality U, the sandstone strikes n. 21° w., dip 60° e. On the old tram track below the Middle quarry, the sandstone strikes n. 24° w., dip 70° e.; and the Wilbur in the hill above strikes n. 49° e., dip 75° w. At the entrance to the Hill quarry, which is an excellent place to examine the unconformity, the sandstone strikes n. 44° w., dip 50° n.e.; and the limestone strikes n. 41° e., dip 75° n. w. On the incline in the North quarry, which is just west of the engine house (marked E on map, pl. 2), the sandstone strikes n. 4° to 6° w., dip 70° e.; and the limestone strikes n. 71° e., dip 10° w.

The nonconformity represents a period of land conditions in this vicinity which continued through the epochs of deposition of the Shawangunk grit, the Medina sandstone, the Clinton limestone and shale, and the Rochester shale and possibly the Lockport limestone. All of these formations, absent from the Rondout section, were laid down farther to the westward and southward, as described by Hartnagel in his paper on the Cobleskill limestone.

Plate 7



Unconformity of the Wilbur limestone and the Champlainic sandstones, near the south end of the Vlightberg at the point marked U on the map [pl. 2]. View looks northeast. See page 1209

Structure of the Vlightberg

The principal structural features seen in the Vlightberg are a monocline and two anticlines, all of northeasterly trend, and a small overthrust block.

1 The Glory Hole vein along the east slope of the hill, is at present a monocline of steep northwesterly dip, though it may have originated as the eastern limb of a compressed or faulted synclinal trough.

2 An eastern anticlinal arch, just northwest of the Glory Hole vein, is seen at the surface at the Delaware avenue quarry at the northeast, in the underground workings of the Spring, Level, and Middle quarries, and again is exposed at the surface in the small arch just east of the Taylor's corner workings at the south end of the Vlightberg.

3 A second, western, anticlinal arch forms the northwestern half of the Vlightberg. The axis of this arch passes through the point J, and just west of the point K on the map [pl. 2], and its western limb is exposed in the steeply dipping Vertical cut along the outcrop of the Becraft limestone [*see* V-V, map, pl. 2].

4 An overthrust block of small extent and uncertain relationships, cut off by the fault 2-2 at the north end of the Vlightberg.

1 Glory Hole vein

The most important feature of the eastern side of the Vlightberg is the long deep cut made in the Glory Hole vein of the cement rocks, which extends with a general strike of n. 60° to 70° e. from the engine house (E) southwestward for about 600 yards to beyond the Middle quarry (M), where it loses its identity.

This "vein" of cement rock has an outcrop at least 20 feet wide that appears on the hillside at altitudes varying from 100 feet at the engine house to about 175 feet between the Hill and the Middle quarries. The vein dips into the hill at the steep angle of 75° to the northwest, and at the northeast end, between the engine house and the Hill quarry, it has been excavated in the Glory Hole workings to a depth greater than 150 feet below tide level. In these deeper workings, and also in

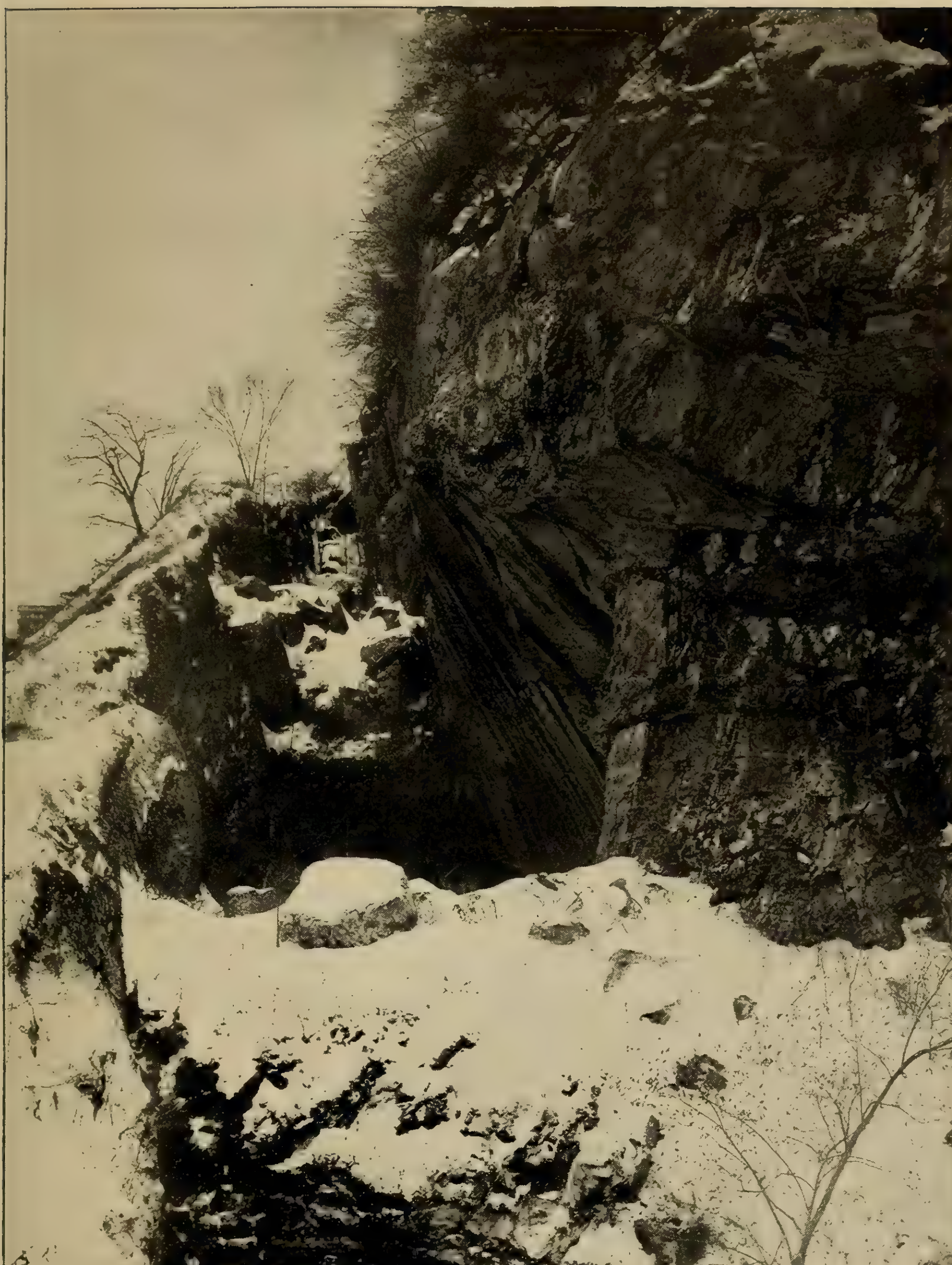
the shallower workings along the vein near the Hill quarry and north of the Middle quarry, the same trend of n. 60° to 70° e., and dip of 75° n. w., are maintained with remarkable regularity in the foot wall of the vein. On the other hand, the trend and dip of the hanging wall of this vein are not so constant and they vary greatly in the vicinity of local disturbances of the cement beds.

Toward the south side of the Middle quarry the Glory Hole vein assumes a flatter position, and at the point U, which is near its southernmost outcrop, its dip is 30° n. w. and its strike n. 55° e.

While at certain points, as at about halfway between the engine house and Hill quarry, shown in the distance of the photograph [pl. 8], the Glory Hole vein is a simple vein about 20 feet thick, there are other sections where the vein has been duplicated and even tripled by diagonal strike faults, the planes of which intersect the vein at small angles, generally 10° to 20°. Such diagonal strike faults, which are in all cases thrusts of small displacement with the upthrow or thrust on the northwest side, are best seen at the north end of the Glory Hole cut [pl. 8 and 9], at the Middle quarry [fig. 2, pl. 12], and at the Hill quarry. At one point near the south end of the deeper workings of the Glory Hole vein, such a diagonal fault brings up a wedge of Wilbur limestone, the angular crest of which rises toward the southwest.

Following the Glory Hole vein through the Middle quarry toward the south end of the Vlightberg, we find that its dip decreases, and that it is split by a diagonal strike thrust fault, with upthrow on the northwest side, into two veins, which south of the Middle quarry give rise to two sharp though small ridges now capped on their northwestern slopes by Wilbur limestone, and showing Champlainic sandstones on their southeastern slopes [*see* pl. 12, fig. 2, 3, 4]. The right hand ridge, with a strike of n. 55° e., on which is the finely exposed section of the unconformity at locality U [pl. 7], is the continuation of the Glory Hole vein, which has veered somewhat to the southeast and which here has a northwesterly dip of only 30°. The second

Plate 8



The Glory Hole cut, looking southwest from the corner of the engine house. The foot wall at the left is Wilbur limestone; the hanging wall is the Leperditia bed. The snow covered mass in foreground is top of a pier.

ridge, designated "vein B," [pl. 12, fig. 3 and 4], with a strike of n. 60° e., dip 30° n. w., appears first as a small wedge-shaped block in the south side of the Middle quarry, the block increasing in size and hight to the southwest till it becomes of the same prominence as that bearing the original vein. The northwesterly dipping Wilbur limestone on the western surface of this "vein B" block is broken in the trough at the bottom of the slope by a small fault, which separates it from the southeasterly dipping Wilbur limestone that covers the eastern limb of the anticline of the Taylor's corner vein. This small fault coincides with the axis of a synclinal fold, which, though here broken, had a complete trough, now eroded, at no great distance to the southwest. Northeastwardly the amount of displacement along the fault plane increases rapidly, and at the Hill and Level quarries the two broken edges of the cement formations are widely separated, how far is as yet undeterminable. At any rate this fault affords a clue to the puzzling relations of the Glory Hole vein and the eastern anticline.

2 The eastern anticline

At the southern end of the Vlightberg the Taylor's corner vein of cement [pl. 12, fig. 3 and 4] is bent up into a sharp anticlinal fold of northeasterly trend, the crest of which is distinguished in the rounded ridge, covered by Wilbur limestone, that extends northeastward from the old Taylor's corner engine house. The southern end of this anticline is cut off by erosion, and a good section of it can be seen along the southeast-northwest portion of Union street [pl. 12, fig. 4]. The eastern limb of the anticline is very narrow at this point, as it extends only to the fault in the bottom of the first trough east of its crest, a distance of perhaps 40 feet. The western limb is of much greater width, and, with a dip of about 45° to the northwest and strike of n. 70° e., it slopes under the high overhanging escarpment of the Manlius and Coeymans limestones. This vein was excavated for a considerable distance underground and it was found to be abruptly truncated along its entire western edge by a small overthrust fault of northwest dip and northeast strike [pl. 12. fig. 3] by which the Champlainic sandstones were

carried upward toward the southeast to form the hanging wall of the vein along its truncated edge. The amount of displacement along this thrust plane has not been determined, as no exploration in search of the missing vein has yet been made.

The axis of the eastern anticline dips at a low angle to the northeast, as can best be seen in the northerly portion of the Taylor's corner workings.

The Middle quarry, which is next northeast of the Taylor's corner quarry, shows a structure quite similar to that of the latter, namely an anticlinal arch dipping slightly to the northeast, its wider western limb dipping steeply to the northwest and finally being truncated by an overthrust fault which brings up the Champlainic sandstones into the hanging wall. The eastern limb of the Middle quarry anticlinal is however somewhat different from that of the Taylor's corner vein. It is wider, and steeper, and, after having been followed in the quarrying operations for some distance, perhaps 150 feet, on its southeast dip toward the Glory Hole vein, it was found to curve sharply downward and to diminish in thickness and eventually to dwindle to a knife edge.

Still farther northeast on the same anticlinal arch are the Level workings, which present essentially the same features in the form of the vein, with the exception that the anticlinal arch has here a small longitudinal trough on its summit just west of its crest. The barren, much contorted zone lying between the eastern limb of this anticlinal and the Glory hole vein is crossed by two or three tunnels or crosscuts, and abundant evidence of slipping along northwesterly dipping planes can be found.

The Spring quarry adjoins the Level workings on the northeast. Here also the anticline appears, but with a slight southwestwardly dipping crest, and with its direction changed toward the left to a strike of n. 42° e. This quarry is just north of the apex of the angle that marks the change in the directrices of the folds of this region, as already referred to on page 1179. The apex falls somewhere between the corner of Delaware avenue and the engine house, and in this small area we find structural features seen nowhere else in this region.

Plate 9

North end of Glory Hole cut, looking from top of second pillar northeast toward the engine house. Note the folded and faulted gray cement in left side of first pillar, and the striated and scaly thrust plane at the bottom of the Prismatic cement in the hanging wall. The foot wall is Wilbur limestone.

The western limb of the anticline has not been explored to a sufficient depth in the Spring quarry to enable us to state definitely what becomes of it, and whether or not it is truncated by a fault in the same manner as are the veins in the other quarries to the south. There are on the surface of the ground some indications of a fault of northeast trend that crosses Delaware avenue at a point about 400 feet west of where the tram track crosses the avenue at the angle, but the plane of a fault intersecting the surface of the ground at this point would pass several hundred feet west of the strike of that deep fault which truncates the veins of the Level and other quarries.

The eastern limb of the Spring quarry anticline presents much the same features as shown in the other quarries.

On the surface of the ground the anticlinal arch shows finely in the Delaware avenue quarry and in the stripped area west of the shaft house at the Spring quarry incline; and an excellent sectional view of it looking in a southwest direction can be obtained on the flats from the old floor of the Spring quarry at the foot of the hill near the junction of Delaware avenue and Crane street. In the Spring quarry face and in the face of the Delaware avenue quarry, which lies above the Spring quarry, a continuous, undisturbed section of the Siluric and Lower Devonic formations as far as the New Scotland beds can be measured. The entire thickness of the Manlius and the underlying cement beds is shown in the face of the old Spring quarry, and the base of the Coeymans limestone is seen breast high above the floor of the Delaware avenue quarry. On the southeast side the beds dip steeply toward the flats. The crest of the anticline is broad, so that the floor of the quarry is almost flat, and at the quarry face the beds show a slight dip to the northwest at the top of the western limb of the anticline.

On the south side of Delaware avenue, between the Spring quarry shaft house and the engine house [pl. 3, sec. 3], is a small knoll of Manlius limestone, the beds of which dip about 30° toward the southeast. This knoll presents a fine example of "imbricated structure," or "schuppen-structur" induced by several nearly parallel minor thrusts from the southeast. These thrusts are peculiar in that their planes, which are from

12 to 15 feet apart, converge toward the surface of the ground. Their effect is to produce a quartet outcrop of the Stromatopora bed of the Manlius limestone, and greatly to increase the apparent thickness of the latter formation. There has been little crushing along these minor thrust planes, and a shear zone of only $\frac{1}{10}$ to 1 inch thickness can be distinguished; but, nevertheless, the opposing faces of rock have well developed slickenside surfaces. Close faulting with almost no shear zones is on the whole characteristic of the dislocations in the limestones of this region. These minor thrusts are very similar to some of those figured by Sir Archibald Geikie, 1888.[1]

The formation of these minor thrusts was probably immediately consequent on the plication of the anticlinal arches, and their origin is assigned to torsion forces that buckled the anticlinal arch.

A most interesting feature of the eastern anticlinal is the pair of approximately parallel tranverse thrust faults of northeasterly dip that transect the anticlinal arch and cut it into three segments. Little trace of these two faults can be distinguished on the surface of the ground, but they have produced important complications of the underground cement veins. The Taylor's corner vein, after having been worked out across the entire width of the anticlinal arch, finally dipped toward the northeast, its foot wall flattened, and the farther edge of the vein was truncated by a northeasterly dipping thrust fault which afforded a hanging wall of Champlainic sandstone. The southern end of the Middle quarry has a higher elevation than, and actually overlies the broken end of the Taylor's corner vein, and it, in turn, at its northeastern end dips steeply and is cut off in similar manner by a thrust plane. Beyond this second thrust plane the same vein is being worked at a higher altitude in the south end of the Level workings. These transverse faults are all overthrusts from the northeast, and in consequence of their presence the segments of the eastern anticline have been "telescoped," so that they overlap each other after the manner of a vertical row of earthenware tiles on a roof.

[1] Recent Work of the Geological Survey in the Northwest Highlands of Scotland. Quar. Jour. Geol. Soc. London. v. 44, fig. 4–21.

Plate 10

Contorted beds over the entrance to Glory Hole incline, just to right of foreground of plate 8. Curved bed over entrance is Leperditia inclosing core of Prismatic. To left of this a wedge of gray cement faulted on itself. The other side of this wedge is shown in plate 9. Upper portion of figure occupied by Leperditia and Prismatic beds. See page 1220

We have here the only direct evidence seen in this vicinity of the existence of a compressing force acting from the northeast, and even this force may be indirectly due to the same torsion stresses that produced the buckling of the anticlinal arch.

It seems appropriate to cite here other phenomena which we consider to have been caused by torsion forces acting after the formation of the main features of the region. Among them are: the virgation of the Glory Hole vein at its southern end; the small diagonal strike thrusts that intersect the hanging wall of the Glory Hole vein, and several similar thrusts seen in the Becraft limestone at the White lime quarry; the diverging minor thrusts of the Becraft limestone in the Vertical cut; and possibly also the small overthrust mass that caps the northern top of the Vlightberg.

3 The western anticline

When passing over the Vlightberg along the line of section 1 [pl. 2 and 3] the Coeymans limestone is found faulted on itself over the hanging wall of the Glory Hole vein. This condition is best seen at the Hill quarry where the lower mass of Coeymans limestone has fallen away from the overthrust plane into the quarry, leaving the deeply striated under surface of the thrust mass finely exposed to view. This thrust mass of Coeymans, which dips at a high angle (almost 80°) toward the northwest, curves upward toward the top of the hill and becomes inverted toward the northwest, and finally is lost just below the crest of the cliff along an approximately horizontal crushed zone that marks the presence here of a dispersed fault. Above this crushed zone the Coeymans limestone appears in its normal attitude exposed in low ledges of northeasterly trend just east of the tenant house on the hilltop. These ledges of Coeymans extend along the entire eastern edge of the hilltop, with an exposure about 50 feet wide, and at a point about midway between the tenant house and the edge of the Middle quarry their strike is n. 50° e., dip 60° n. w.

At the southern end of the Vlightberg the strike of the Coeymans and New Scotland beds veers to the west around the spooning-up end of the small synclinal trough that occupies the northward-opening swale on the top of the Vlightberg.

Through the point marked J on the map, plate 2, passes the axis of the western anticlinal arch, on the crest of which are exposed ledges of Coeymans limestone that show in the field on top of the hill overlooking the Vertical cut. These Coeymans beds dip slightly toward the northwest. A short distance down the northwestern slope of the hill the New Scotland beds are found, and near the foot of the hill the steeply dipping Becraft limestone has been quarried in the Vertical cut [V-V, pl. 2]. The limestone in the Vertical cut stands nearly on edge, with a strike n. 75° to 80° e., and its apparent thickness is somewhat increased by a virgating series of several minor thrust faults. These faults radiate from an axis parallel to the strike of the limestone and located a short distance below the floor of the quarry, they cut the bedding planes of the limestone at low angles, and in each case the upward thrust is on the northwest side.

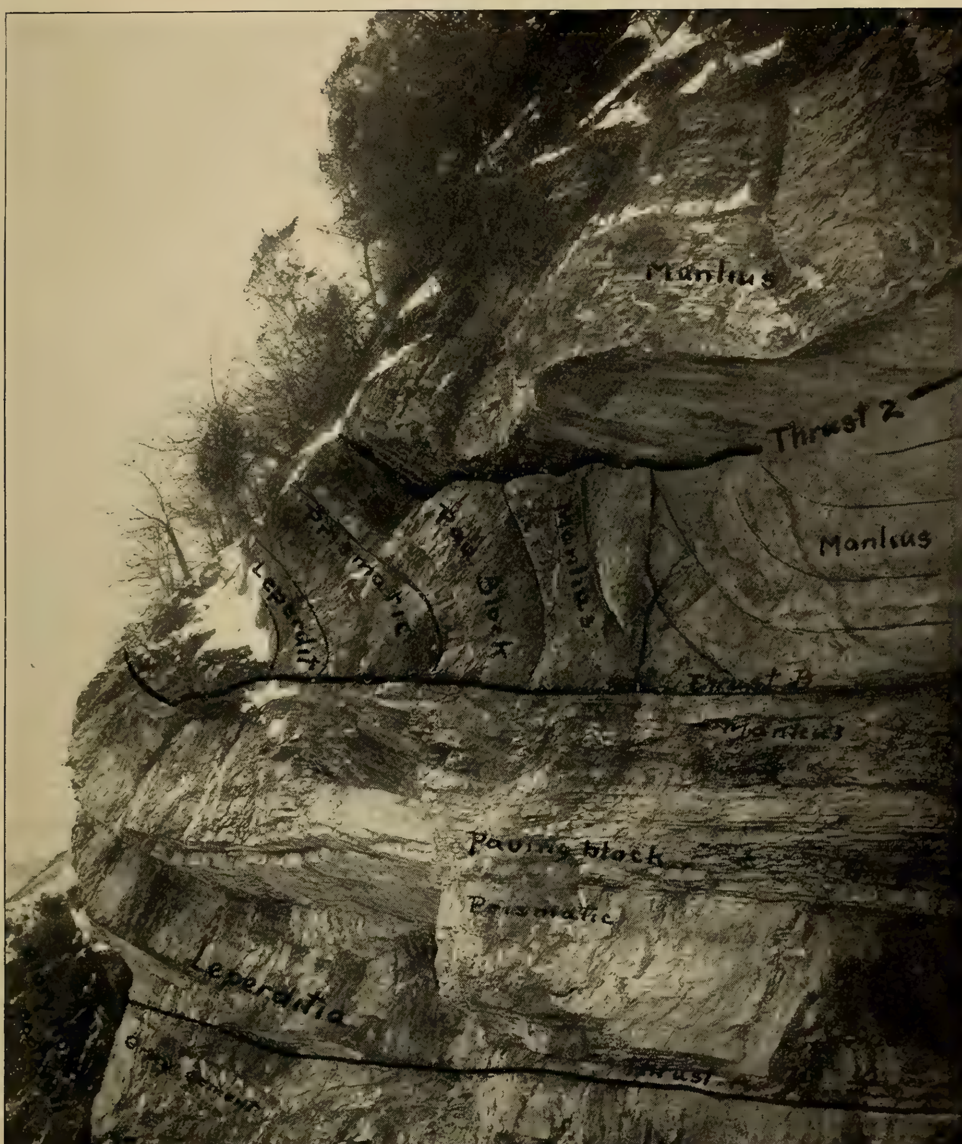
The bowl-shaped area just north of the point J is filled with drift deposits, so that its substructure can not be determined.

4 The Vlightberg overthrust

The western and northern edges of this overthrust plane are marked on the map [pl. 2] by the heavy black line 2-2, and its position is roughly indicated on section 2 [pl. 3].

On the south side of Delaware avenue, just beyond the shaft house of the Spring quarry incline, there is a knoll showing an anticline of Coeymans limestone, the axis of which points southwestwardly across the fields toward the Vertical cut. The path that crosses the east side of this knoll leads under the cliff of New Scotland limestone on the north side of the Vlightberg and then joins the lane that runs to the tenant house on the hilltop. On the northwest side of the lane is a field with no outcrops of rock. The lane itself runs over Coeymans limestone which outcrops at intervals, dipping to the east at low angles. Along the left or eastern side of the lane the New Scotland limestone of the low cliffs is very much shattered and dips steeply to the northwest. Continuing on up the lane, the Manlius limestone, with strike n. 20° e., dip 10° e., appears at the point K on the map, at the angle of the road where it turns up the hill toward the house. A little farther on, a low escarp-

Plate 11



Faulted and folded beds of cement rock and Manlius limestone in face of cliff over the Glory Hole incline. This view is immediately above that shown in plate 10. See page 1220

ment crosses the road diagonally and can be traced for some distance to the right into the field and in the opposite direction toward the northeast into the woods. This escarpment is formed by the upper part of the New Scotland limestone, which has here a strike of n. 60° e., dip 55° n. w., and which marks the western edge of the overthrust mass. In the woods northeast of the lane a narrow strip of basal Becraft limestone overlies the New Scotland at the edge of the escarpment, also dipping steeply to the northwest.

The contact plane of this overthrust can not be seen along the northwest side of the hill, but its course is plainly indicated by the topographic features, the sharp angulation of the slope, and the narrow gully which extends for a short distance through the woods along the foot of the slope. On the north and northeast side of the hill the thrust plane can be readily distinguished, specially in the cliff over the Glory Hole and Level inclines. Here it is seen as a well marked plane cutting diagonally across the cement and Manlius beds at about the hight of the peak of the roof of the head-frame shed [thrust 2, pl. 11]. On the eastern slope of the hill, between the engine house and the Hill quarry, this plane seems to rise toward the southwest, and its location is soon lost, probably through dispersion of the fault.

This thrust is from the southeast, and it involved in its movement only the upper layers of the eastern anticline, and shoved these a short distance along an almost horizontal plane toward the northwest till they rested on the southern limb of the western anticline. It seems to belong to the system of minor convergent thrusts, described on page 1215, as imbricating the Manlius limestone in the area north of the engine house. Its position is only a few feet above the uppermost of those thrusts, and its attitude is more nearly horizontal. We see no reason for associating this Vlightberg thrust with the much more extensive White lime quarry overthrust of the North hill, described below.

The outcrops of Coeymans and Manlius limestone along the lane probably belong to the southeastern limb of the western anticlinal arch.

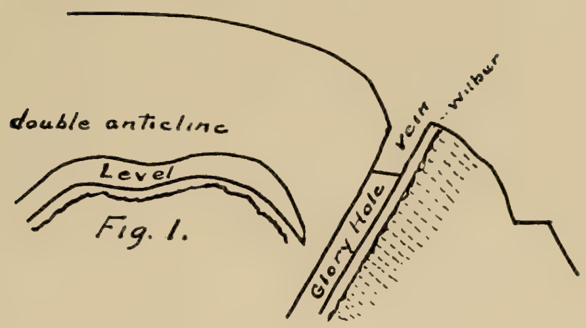
Contorted beds at mouth of Glory Hole

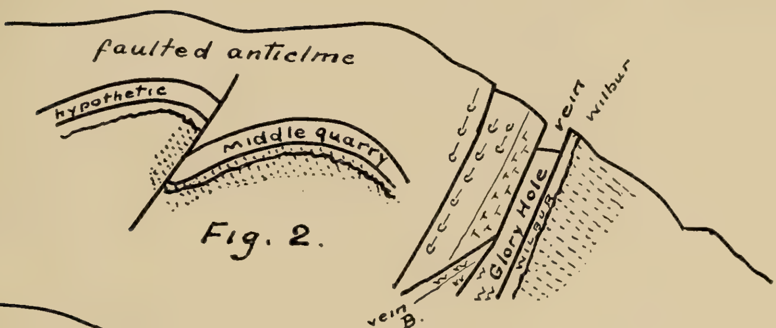
Before leaving the discussion of the Vlightberg, we wish to call attention to the complex and highly interesting folding of the rocks over the mouth of the Glory Hole incline [see pl. 8 to 11]. Of these plates, numbers 8, 10, 11 are adjoining views all looking southwestwardly from the engine house. Plate 8 is from the southeast corner of the engine house, looking along the Glory Hole cut. Plate 10 is a view of the lower portion of the cliff from the platform of the Glory Hole head-frame on the west side of the engine house. Plate 11 shows the upper portion of the cliff as seen from the western edge of the engine house roof, and its lower portion duplicates the upper portion of plate 10. The relations between plates 8 and 10 will be better understood when it is recognized that the small wedge of cement rock in the top of the pillar in the right of plate 8 is the same wedge that shows to the left of the center of plate 10. It is shown also in the lower left hand corner of plate 11, where it is marked "gray cement," and a view of its opposite side is seen in plate 9, where it is marked "H?."

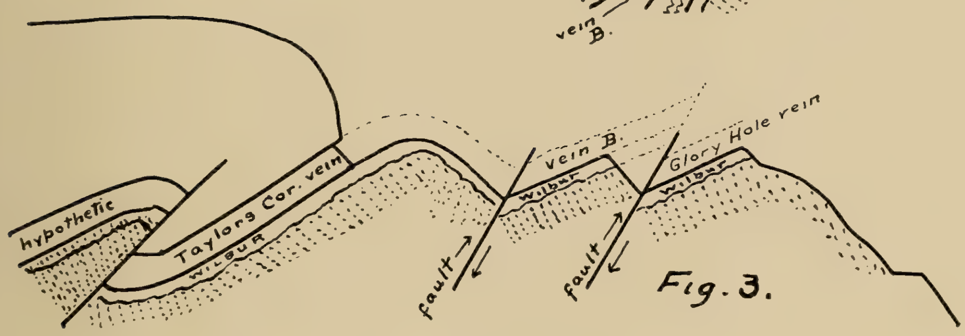
Overhanging the Glory Hole incline is a long closed recumbent underfold of Leperditia limestone containing a core of Prismatic cement. This fold can be traced along the foot of the cliff toward the right for about 30 feet, till it is lost in the vicinity of the Level incline. To the left of this fold, in the top of the pillar which was left to support this very unstable portion of the Glory Hole hanging wall, are wedges of cement rock, the structure of which is best shown in plate 9. These wedges are remnants of a faulted mass, produced by one of those diagonal strike thrusts described on page 1212, by which the Glory Hole vein was here duplicated to form what the miners call a "double vein."

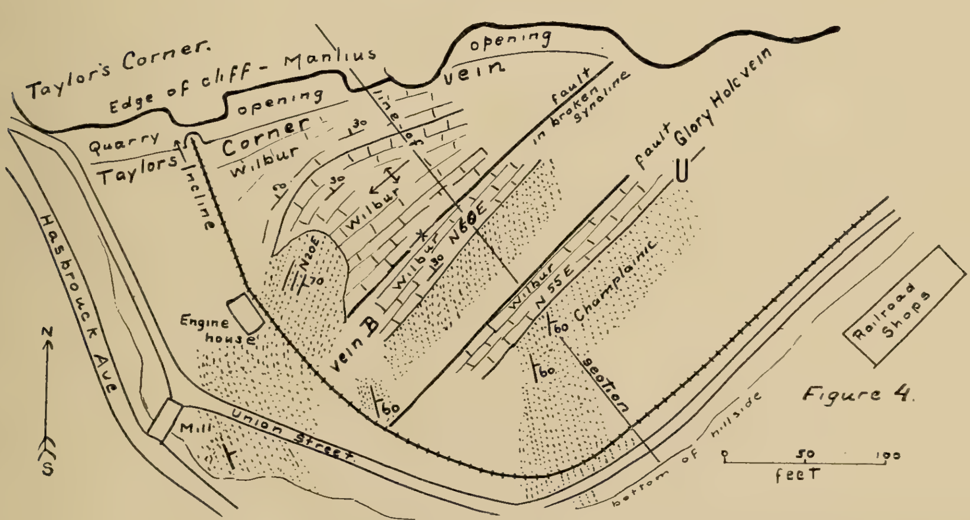
Above the recumbent fold is seen the edge of a thrust plane [thrust A, pl. 11], that appears to be the continuation of the fault plane which produced the beautifully striated and scaly surface on the hanging wall of the Glory Hole cut, shown in plates 8 and 9. Next above is a series consisting of Leperditia, Prismatic, Paving block, and lower Manlius (beds 12-14 of section, p. 1183), which are terminated above by the almost hori-

Plate 12









Sections across the Vlightberg and sketch plan of the southeastern corner of the Vlightberg to show the relations of the Level, Middle and Taylor's corner veins of the eastern anticlinal arch to the Glory Hole vein, and also the virgation of the Glory Hole vein at its southern end. See page 1211

zontal thrust plane of the Vlightberg overthrust, 2-2. Above this 2-2 thrust is more Manlius and, at the top of the view, the Coeymans limestone.

The middle block, between thrusts A and 2, shows a very fine example of beds dragged beneath a thrust plane. The overthrust mass above plane 2 moved in a direction n. 40° w. The broken edges of the under segment were caught by the moving mass, curled up, as shown at the left of the center of plate 11, again broken off, and a small intermediate thrust plane (thrust B) about 50 feet wide was formed. Along this latter plane the small broken off segments of the beds involved were carried along and actually jammed farther into the face of the cliff. Thrust B has a true overthrust plane at the edge of the cliff at the left of the picture which diminishes to a mere sliding plane between normally superimposed layers of the Manlius limestone at the right side of the view.

The North hill and the White lime quarry thrust

Sections 3, 4 and 5 of plates 3, 4 and 5, illustrate the structure of the North hill, which is very much simpler than that of the Vlightberg. With the exception of the extreme southeastern corner, the entire area north of Delaware avenue depicted on the map [pl. 2], exhibits a shallow synclinal structure with the beds at the eastern edge of the trough dipping steeply westward. The anticlinal arch seen in the Spring and Delaware avenue quarries does not constitute one of the structural features of the North hill, as its axis has an east-northeast trend that diverges from the almost northerly direction of the base of the hill slope.

The strike of the formations on the North hill is generally about n. 20° e., excepting near Delaware avenue, where, in the vicinity of the Gross quarry and Gross residence, the strike veers to the southwest and west with a corresponding change in the dip to northwest and north. Farther west at the first intersection of the railroad with the avenue the southwest strike is again resumed in the Oriskany pebble bed.

Along the line of section 3, which is about on the line of Delaware avenue, the various formations succeed each other in normal sequence of Manlius, Coeymans, New Scotland, Becraft, Port Ewen and Oriskany. There is evidence of diagonal strike

faults at a few points on this line, as in the south end of the Gross quarry, and in the ridge of Oriskany west of the Gross residence, by which the apparent thickness of the Becraft and Oriskany beds is somewhat increased, but the order of superposition of the formations is undisturbed.

On the line of section 4, however, taken a few hundred feet north of the avenue, the conditions are quite different. The sequence of the formations is normal up to the Becraft limestone of Gross quarry, and then a prominent thrust plane cuts off the Becraft, and above the plane is found the Manlius limestone. Above the Manlius and to the westward the formations are repeated in normal order; Manlius, Coeymans, New Scotland, Becraft, to the western slope of the hill, which at the line of this section is cut into the almost vertical Port Ewen beds.

Several hundred feet farther north the same conditions are found along the line of section 5, plate 5, which passes through the White lime quarry, W-W on map, plate 2.

The White lime quarry overthrust fault, which is indicated on map, plate 2, by the heavy black line marked 1-1-1-1, has been traced by us northward from Gross quarry to where it passes just east of Terry triangulation station, and throughout this distance its position and horizon were found to be remarkably constant. It follows very closely the western edge of the easternmost Becraft limestone vein, and its location is usually indicated by a more or less prominent escarpment on the overthrust side or by a gully of erosion in the somewhat crushed Port Ewen beds below the thrust plane.

At the middle of the Gross quarry, about 200 feet north of Delaware avenue, the Becraft limestone strikes n. 70° e., dips 20° n. w., and has above it at the edge of the quarry face a few feet of lower Port Ewen beds, which are continued along the southerly slope of the hill to a point back of the Gross residence. At the north end of the quarry the Becraft strikes n. 65° e., dips 20° n. w., and its upper portion, the thin blue layers, are cut off by the thrust, above which the Manlius limestone appears with strike n. 80° e., dip 5° n. These Manlius beds just above the thrust plane are the thinly bedded, dark blue gray layers containing S p i r i f e r v a n u x -

Plate 13

View of the White lime quarry, looking northeast, and showing the Rondout (erroneously marked Salina) beds forming an escarpment above the fault plane in the hillside on the left. The position of the thrust plane is indicated by the heavy line. The Port Ewen beds occupy the center of the picture, underlying the roadway, and the Becraft limestone has been quarried from the depression on the right.

emi, Leperditia alta, and Tentaculites gyracanthus, which lie below the Stromatopora bed, and they correspond to layers 14 and 15 of the Spring quarry section. A short distance farther up the Stromatopora bed of the Manlius is succeeded by the heavy gray and dove-colored limestones, and at the brow of the hill the basal bed of the Coeymans appears with a flat dip to the northwest. The Coeymans occupies a narrow belt, but forms a well marked ridge that continues northward through the woods.

On the line of section 4 the New Scotland beds occupy a broad belt with two prominent longitudinal ridges caused by the more resistant lower and upper layers. The attitude of the beds on the surface indicates that they are flexed, as shown in the section, into a small trough and a broad low anticlinal arch with steeply dipping western limb.

Near the western edge of the hill the Becraft limestone vein 2, dipping steeply to the west with a north-northeast strike, forms a low ridge, on the western slope of which the Port Ewen beds are exposed standing quite on edge. The lower portion of the hill slope is covered with talus, so that no outcrops are found till the western side of the narrow valley is reached, where the Esopus grits are extensively exposed in horizontal attitude.

Section 5, through the White lime quarry, presents quite similar conditions. On the east the Becraft vein 1 is finely exposed in the deep open quarry [W-W on map, pl. 2]. The strike of the Becraft on this vein is quite sinuous. The main strike is n. 25° e., but for short distances, where the vein is diverted by diagonal strike faults, its trend is n. 15° e., and at one point, n. 5° e. Its dip is steep to the west, with local modifications. At the south end of the quarry the hanging wall shows a sharp fold, above which the dip is inverted toward the west, and at the surface of the ground there are other traces of westward drag.

The floor of the quarry can be reached through an entrance tunnel in the foot wall from the road that passes along the eastern base of the hill. A second prospect tunnel at the level of the quarry floor and about on a line of section 5, was driven about 150 feet into the hanging wall of the quarry. This tun-

nel traversed part of the Port Ewen beds, and at increasing distances from the mouth of the tunnel the bedding planes were found to have flatter dips, which diminished from about 65° w. near the hanging wall to about 30° w. at the blind end of the tunnel.

Above the western edge of the quarry [see pl. 13] is a wood road in which ledges of Port Ewen limestone outcrop at intervals, and at the foot of the escarpment west of the road is the eastern edge of the overthrust. The position of this thrust plane is indicated by the heavy black line in the photograph. The escarpment above the thrust plane, imperfectly shown in the woods at the left of the photograph, contains the upper member of the cement series (Rondout beds) and the lower portion of the Manlius limestone. A short inclined shaft was sunk for the purpose of prospecting the cement beds, and this incline affords some interesting data on the attitude of the thrust plane. The hanging wall dips 30° w. at the surface, but at 25 feet underground this dip flattens to 14° w. The foot wall of the cement dips about 15° w. throughout, and this is considered to be the approximate dip of the thrust plane at this point.

About 250 feet west of this first escarpment, on the farther side of a small valley eroded in the middle layers of the Manlius, is a second escarpment about 40 feet higher than the first and capped by the basal layers of the Coeymans, which dip to the west at a low angle. It was in this escarpment, at the point where it is crossed by the path that leads from the north end of the White lime quarry westward through the woods, that the fossils described on page 1188 were obtained.

Continuing westward along this section line, we cross a second ridge of flat upper Coeymans beds, then a broad ridge of New Scotland beds which present steeper inclination toward the west, and at about 750 feet west of the road appear the lower layers of the Becraft vein 2. The outcrop of this Becraft vein is wide because at its eastern edge the beds dip about 30°, and at its western edge this dip suddenly increases to 75°. Then on the crest of the ridge overlooking the western slope of the hill is a belt occupied by about 110 feet of Port Ewen beds with an 80° westerly dip. Halfway down the slope

of the hill are exposed the Oriskany pebble beds and still lower down, near the foot of the slope, is a small outcrop of Esopus grit with a correspondingly steep dip. Along the foot of the slope is the dried-up bed of a stream, and on the other side of this small valley the Esopus grits lie horizontally, or dipping slightly eastward.

East and west cross sections of the hill taken at points farther north, as at the Old quarry (O), Cloonan's quarry (C), and at the Terry triangulation station, show that the various formations extend with the same simple structural features in more or less regular belts for a considerable distance to the northward, the width of the belts of exposure varying locally according to the topography of the eroded land surface.

Summary

The overthrust mass which has been thrown to the west at least 1100 feet forms a veneer to the top of the North hill. The dip of its beds varies from 15° to 25° w. along the eastern edge of the thrust mass, to zero along its central line. On its entire western edge the dip is high, and at one point on the cross road west of Terry station the Oriskany beds dip slightly beyond the vertical. The high dip of the western edge is probably due to drag and underturning of the free edge of the thrust block. This thrust is probably of the nature of the so called "erosion thrust,"[1] where the sliding mass has progressed over a land surface.

The southern end of the thrust is drawn on the map as curving to the southwest and then to the west-northwest. This is due to the southward slope of the end of the hill by virtue of which the thrust plane intersects the surface of the ground along an approximately east and west line. On the upper, northern, sides of this line the Manlius, Coeymans and New Scotland limestones overlie the Port Ewen beds beneath and south of the thrust plane; and, at the point B, the second vein of Becraft, in the overthrust mass, abuts against the Oriskany beds of the underthrust section.

The present attitude of the thrust plane, dipping 15° toward the west, can not be its original attitude. An orogenic force acting from the eastward might produce a thrust with a plane

[1] Willis. 1893. p. 223.

approaching horizontality; but this White lime quarry thrust has a plane surpassing horizontality, dipping to the westward, and we infer that since the formation of the thrust plane, the entire region has been tilted toward the west, perhaps during the formation of the Posttriassic geanticline of eastern New York and the Connecticut valley.

Conclusion

Our interpretation of the Vlightberg structure is as follows. The main structural features originated in a sigmoid flexure, with broad arch on the northwest and narrow trough on the southeastern side, which was formed by orogenic forces acting from the southeast. This sigmoid fold, instead of being a typical Appalachian overfold toward the northwest, is an *underfold* in that direction, in which the steeper limb of the flexure was on the southeast side. It is now a compressed underfold, with its synclinal trough broken through stretching of the middle limb, and its anticlinal crest bulged up and broken by longitudinal thrusts formed as a result of the continued tangential pressure acting on a mass of strata carrying little if any superficial load. The Glory Hole vein is the eastern limb of the synclinal trough of the sigmaflexure. The eastern edge of the Middle and Level veins is the common or middle limb of the flexure, which, through stretching, has been broken from the lower edge of the Glory Hole vein, and shoved far upward and over southeastward into its present position. The longitudinal fault between the eastern and western anticlinal arches is a break thrust along the axis of a small synclinal trough that formed, in consequence of continued compression, on the broad summit of the original arch.

The mass of the Vlightberg overthrust consists of the upper layers of the crest of the arch, which have been displaced and moved to the westward by the compression of the trough.

The smaller minor thrusts have already been explained as having been caused by torsion movements.

In the North hill we see a typical Appalachian overthrust formed from a fold of which the steeper slope was toward the west; a condition the reverse of that seen in the Vlightberg.

Some observations on cleavage were made, and we are satisfied that the more prominent cleavage of the different beds was

induced in them before the beds were flexed and broken into their present attitudes.

Finally, all the structural features, with exception of the westward tilting of the White lime quarry overthrust plane which has been otherwise accounted for, can be assigned to the typical Appalachian orogenic movements at the close of the Paleozoic era.

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TORSION OF THE LAMELLIBRANCH SHELL

An Illustration of Noetling's Law

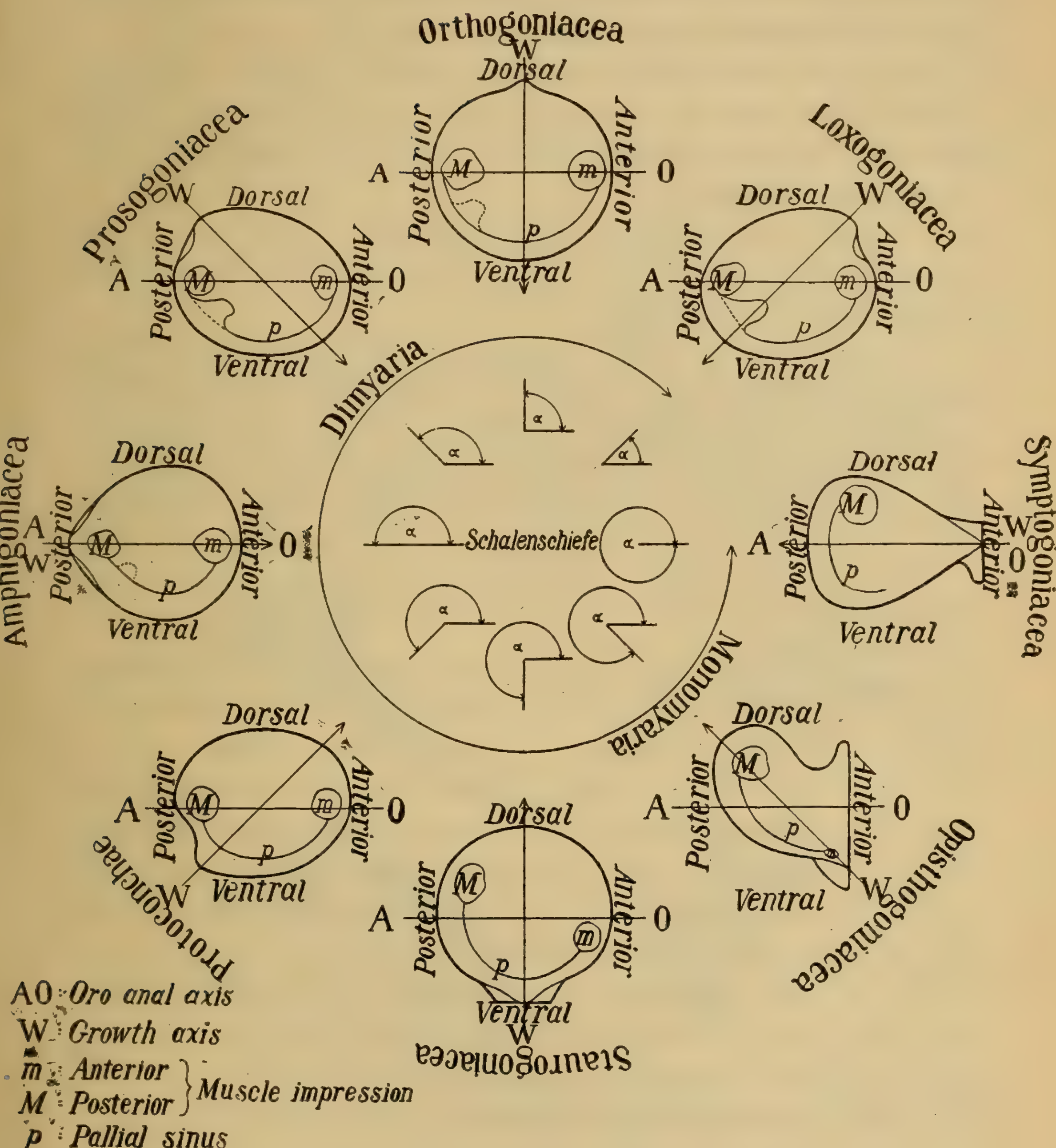
BY JOHN M. CLARKE

Noetling's law of torsion in the lamellibranchiate shell, as set forth in one of his recent publications on the morphology of these mollusks[1], involves the conception that the so called beak of the shell is an unstable position; it is a point of inception of shell growth, but in the various groups of these mollusks the relation of its position to the true axis of the animal itself varies through the entire circle from 0° to 360°. If thus the beak is a variable in position, the current orientation of the shell is reduced to a pure convention and we must, as Noetling concludes, have reference to the fundamental axes of the animal, directly or by implication, for the correct posit of the organism. Variable with the beak is the line of most rapid shell growth which departs from the beak, the ridge which in oblique or elongate shells is commonly called the "umbonal ridge" and which for all shells Noetling terms the crescence-line (*Crescenz-linie*).

The fundamental and unvariable axial line is that running from mouth to anus and is termed the oro-anal axis. The ordinary value of the terms "hight" and "length" as applied to the shell when referred to this constant axis are lost and Noetling regards as *length* the actual length measured on the oro-anal axis. With this line derived from the position of the animal within the shell the empirical "length" sometimes coincides in forms like Venus and other Sinupalliates. In Pecten however the oro-anal axis or true length, is the distance as usually expressed between the hinge line and the basal margin of the valve, hence the "hight." Thus there is here and elsewhere an inversion of current terminology.

The angle made by the constant or oro-anal axis and the variable or crescence-line is an index to the degree of torsion or revolution of the animal with reference to its valves. This angle is termed the *Schalenschiefe* or angle of obliquity (a) and of course

[1] Noetling, Fritz. Beiträge zur Morphologie der Pelecypoden: Neues Jahrb. für Mineral. 15 Beil. bnd. 1902. English abstract by R. Ruedemann in Am. Geol. Jan. 1903, p. 34.


Orthogoniacea
Prosogoniacea
Loxogoniacea
Amphigoniacea
Symptogoniacea
Protoconchae
Opisthogoniacea
Staurogoniacea
Dimyaria
Monomyaria
Schalenschiefe
Dorsal
Ventral
Posterior
Anterior
AO : Oro anal axis
W : Growth axis
m : Anterior
M : Posterior
Muscle impression
p : Pallial sinus

theoretically if not actually has all values from 0° to 360°. In the inserted diagram Noetling chooses to take eight points equidistant on the circle as expressions of eight groups but it is not to be assumed that these groups have either coequal value or are other than links in this circular chain.

1 $\alpha > 0°$ but $< 90°$. The axes make an acute angle and growth takes place in a posteroventral direction. These are the Loxogoniacea and are representd by Venus and a large group of sinupalliate Dimyaria.

2 $\alpha = 90°$. The axes stand at right angles; growth takes place ventrally, perpendicular to O — A. These are the Orthogoniacea represented by Pectunculus.

3 $\alpha > 90°$ but $< 180°$. The angle of the axes is obtuse and growth takes place anteroventrally. These are the Prosogoniacea represented by Mesodesma and Nucula. It is to be here noted that this expression is just the reverse of that of the Loxogoniacea the two standing in the relation of left and right valves of Venus. Here as well as in groups 4 and 5 the beaks are truly opisthogyre and current characterization of these valves consequently erroneous.

4 $\alpha = 180°$. Both axes coincide but growth is forward rather than backward as in 8. No examples are known. Noetling believes they should be looked for among paleozoic forms.

5 $\alpha > 180°$ but $< 270°$. These are the Protoconchae. Growth takes place dorso-orally and the ventral organs and pallial line would lie close beneath the umbo. No examples of these were recognized, but it is thought that such forms will be found among the paleozoic species.

6 $\alpha > 270°$. These are the Staurogoniacea, mathematically like group 2 but with growth in the opposite direction, i. e. dorsally instead of ventrally. No examples are known but these are also to be sought in the paleozoic.

7 $\alpha > 270°$ but $< 360°$. The axial angle is again acute, the growth posterodorsal. These are the Opisthogoniacea and embrace Avicula and the Heteromyaria.

8 $\alpha = 0°$ or 360°. That is the axes coincide. These are the Symptogoniacea and are represented by Pecten. Growth is posterior. The species are Monomyarian.

In Noetling's diagram, of which a copy is given on page 1229, it will be observed that coincident with these variations in the angle of obliquity is the passage from the Dimyarian into the Monomyarian divisions. This brief statement of Noetling's determinations should be supplemented by the reader with the perusal of the original paper or the English abstract as cited.

In elaborating the genus Lunulicardium which is so extensively represented in the Intumescens zone of western New York I have secured some very delicate barite replacements of the valves of Lun. clymeniae which retain the protegulum and give some indications of the value of torsion of the shell as an ontogenic character and it has become possible also to make some observations on the probable phylogenic significance of the same feature. Lunulicardium has been commonly regarded as a bivalve with a long and wide byssal opening. Beushausen has shown that the beaks in a certain subdivision of the

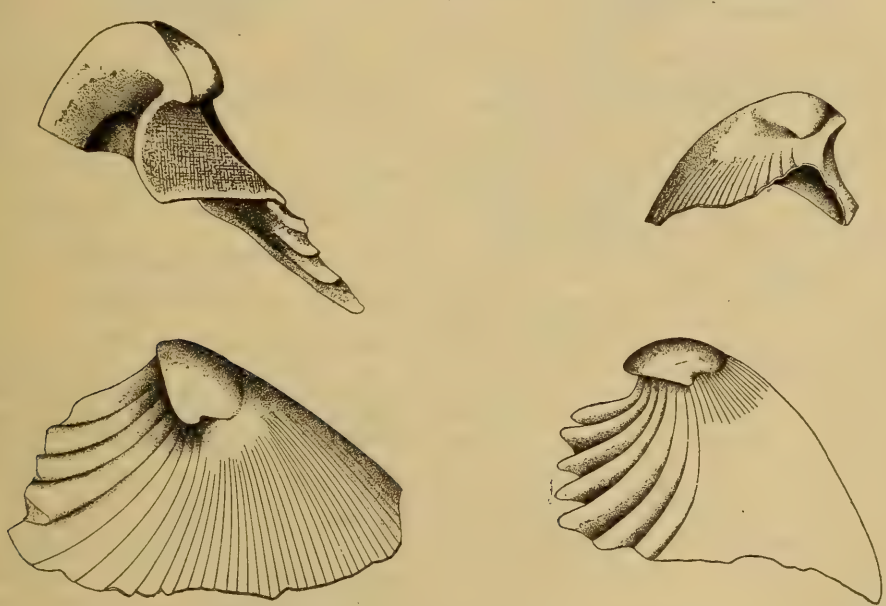


FIG. 1–4 Umbonal parts of Lunulicardium clymeniae showing triangular area and the attitude of the prodissoconch with reference to the mature shell. The apex of the larval shell is directed obliquely backward and its posterior end is the umbonal point of the adult

genus (Chaenocardiola) to which Lun. clymeniae belongs are opisthogyre. We have, in a memoir on the Lamellibranchs of the Intumescens zone in New York, presented a careful analysis of the generic characters but it here suffices to state that the evidence supports the construction of the hiatus between the valves as a byssal orifice while the umbo of the adult shell and the

apex of the prodissoconch are distinctly turned away from the byssal cleft or backward.

With this orientation of the shell the beaks are opisthogyre. The larval shell or prodissoconch lies with its apex or primitive beak directed downward or toward the postlateral extremity of the adult shell, so that the original posterior extremity of the larval shell actually lies at and constitutes the beak of the adult. This relation is shown in the accompanying figures. The shell has in growth actually twisted with reference to the animal and the axial line which we have marked *o-a* has apparently traveled through a large angle to reach the corresponding position in the adult, O-A. The musculature consisted probably of a single adductor corresponding to M on Noetling's diagram. This expresses itself on the best preserved internal casts as a simple moderately large scar as shown in the figure adjoining of Lun. hemicardioides or it may be an approximation of two central scars as seen in Lun. mülleri. In the former the condition seems to be the outcome of fusion of the approximate scars of the latter. The shell is thus in effect Monomyarian, though of Dimyarian inception.

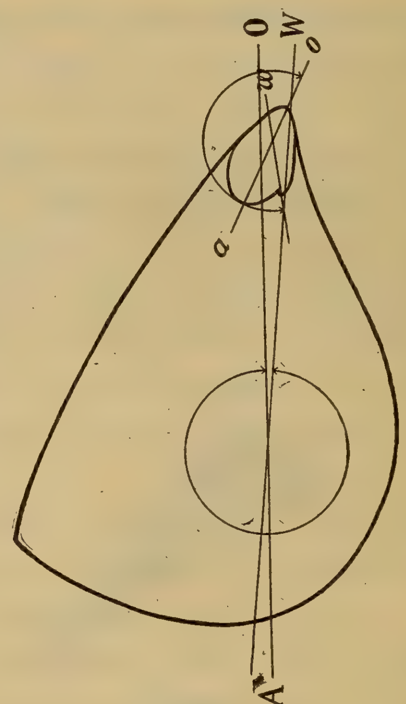


Fig 5 Diagram giving outline of adult Lunulicardium clymeniae with larval shell attached: O-A, oro-anal axis in adult shell; *o-a* the same in young shell; W, *w*, crescence line in the two. The lower arc indicates the very large critical angle for the adult stage, the upper arc, the critical angle for the young stage. The former is normal to a position between the Opisthogoniacea and Symptogoniacea, the latter in agreement with the critical angle of the Protoconchae. In comparing this with Noetling's figures it is necessary to bear in mind that here the exterior of the valve is represented while in that the interiors are given. This will account for the apparent reversal of direction in the two

If now the shell of Lunulicardium be construed and oriented as a Dimyarian then the angle between O-A and W (crescence-line) is less than 90° and conforms to this angle in the extreme Dimyarian line. But in such orientation we unavoidably reverse the extremities of the oro-anal axis, the anal extremity, or A, appearing on the byssal side which we know to be a condition not exist-

ing in the lamellibranchs. The inference therefore that Lunulicardium has little to do with the Dimyarians is supported by empirical evidence of a single adductor or median approximation or fusion of two adductors. Hence orienting the shell as Monomyarian posited between Avicula (Opisthogoniacea) and Pecten (Symptogoniacea), on the basis of its muscular and byssal structure, we find that the critical angle is exact for the position taken. We take this as excellent confirmatory evidence of the Monomyarian affinity of the genus.

FIG. 6 Lunulicardium mülleri. Internal cast showing approximate muscle scars

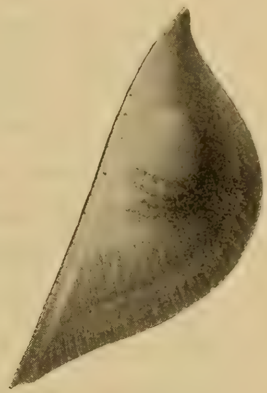


Fig. 7 L. hemicardioides with single large adductor scar

In following the torsion backward from the adult condition to the prodissoconch we find that it passes through the angles necessary to bring it with precision to the condition of the Protoconchae and the relations of the axis in the latter also correspond with those of the prodissoconch[1]. I believe therefore that the prodissoconch stage is an actual representative of the Protoconchae condition and that the stages of torsion of the Lunulicardium shell in subsequent growth are indicative of its phylogenic stages of progress toward the Monomyarian stock. This conclusion is based wholly on external characters and the fact of actual observed torsion in the shell from youth to adulthood. The Protoconchae being theoretically the primitive lamellibranch condition, we may never come to know it except in this or a similar manifestation. The supposed position of the pallial line in this group, just within the hinge, is a feature on which the nature of our material permits no observation.

[1] The reader will note that we are here dealing with the *exterior* of these shells. Noetling's figures are based on interiors; hence the relations of the latter and our figures are reversed.

SOME DEVONIC WORMS

BY JOHN M. CLARKE

Plates 27 and 28

Though trails and tubes of Annelids are of sufficient frequency in Paleozoic rocks to indicate the abundance of these creatures from early Cambric time onward, yet the actual bodies of worms have been so seldom reported that an additional discovery of them seems to justify record. Paleozoic remains believed to be Annelid bodies of errant worms have been described from the Cincinnatian by Ulrich, and Ruedemann has recently given an account of certain leechlike worms called Pontobdellopsis from the Utica shale of New York. We have before us a series of specimens taken from the upper Devonic of New York which seem to us correctly interpreted as bodies of Chaetopod worms directly allied to Aphrodite, the well known sea mouse of north Atlantic coasts which we have had abundant opportunity to study in its natural resorts. They have been collected from certain fine grained felspathic argillaceous flagstones belonging to the final phase of Portage sedimentation in the town of Italy, Yates county, and in the Tannery gully at Naples, Ontario county. Of one, whose structure seems rather the more puzzling, there is a number of specimens, of which in two instances we have opposite sides representing dorsal and ventral aspects, which it may be here said are not greatly unlike because the tenuity of the body substance save on the back has made the latter the predominant expression. These are all from the former locality. Hasty examination of these specimens might find in them a suggestive resemblance to the loose, detached rays of short armed Ophiurans. We call attention to this resemblance lest the sapient critic fall into travail at this point. Another species is represented by several clearly defined examples from the Naples locality, where it is associated with Paropsonema cryptophyum and some other unusual species.

The basis of comparison of these with existing Errant Annelids lies in the apparent presence in both of a double series of transverse scuta or hardened overlapping plates on the back. Such structures are found among living Polychaete worms only in the

family Aphroditidae and we may here introduce so much of the characterization of these forms as pertains to the interpretation of the objects in hand:

W. Blaxland Benham in the *Cambridge Natural History* [v. 2, 1896, Polychaet Worms, p. 309] says:

The most characteristic feature of this family and one by which its members are absolutely distinguished from all other Chaetopods, is the possession of scales or "elytra" on the back. These flattened dorsal cirri are of a somewhat horny texture and are carried, generally, on alternate segments of the body, filamentous cirri occurring on the other segments. In the subfamilies Hermionina and Polynoina the elytriferous segments are 2, 4, 5, 7, 9 etc., up to 23; then every third segment. The worms are usually short with some thirty-five to forty-five segments, though Sthenelais and a few others have many more. In many cases these elytra are relatively of large size extending backward as broad scutes in two lateral series which may or may not meet and slightly overlap in the middle line. The posterior edge of each scute overlaps that next behind it. In the well known case of Aphrodite, the "sea-mouse", the elytra are covered by a felting of hairlike threads but Hermione, an allied genus, has them fully exposed.

The representatives of both of these genera are short, broad and oval worms. We find no statement as to the alternation of the scutes in these forms except that they are "arranged as in Polynoe" where such alternation prevails in most instances. Among the Sigalionina which have longer vermiform bodies "the elytra are in alternate segments up to the twenty-sixth and posteriorly on every succeeding segement" [*op. cit.* p. 313]. Such structures represented by the combination of form and scute-bearing segments we find in our specimens, together with the presence in the case of one species of conspicuous and heavy tufts of marginal setae and in the other sparser hairs plainly arising from extended segmental parapodia. We briefly describe these specimens.

1 Four examples are elongate oval bodies having the outline of a short willow leaf, rather blunt at one end and tapering to a more acute angle at the other. Two of these specimens preserve both obverse and reverse of the body and the markings of one side are sharper than on the other; it is evident that they have been impressed from one side to which they properly ap-

pertain, into the other. The more strongly marked or by analogy the dorsal surface carries a narrow median elevation running from the blunt end to near the acute extremity; it becomes continuously more obscure toward this end and may there fail to cause any interruption of the surface. The more complete of these specimens carries about 55 transverse segments, others carry from 40–50 according to the degree of their completeness. These segmental divisions are produced by oblique depressions departing from the axial line of the body, bending forward toward the margins but over the median and anterior parts becoming more transverse. These depressions bound the surfaces of oblique overlapping plates directed backward or toward the blunt extremity of the body. The plates appear to be continuous across the full width of the body but are narrowest at the axial line and broader outward, their fore and aft width apparently being at about half the distance between the axis and the outer margin. Their edges are frequently broken off in detachment and the posterior plates appear to be longer and better defined than the others.

These plates (if they are correctly thus interpreted) are rather narrower than similar structures in living species so far as our observation has extended and yet it is not clear to us what part of their actual width has been concealed by their oblique direction into the matrix. The overlap is on the anterior surface of each plate and the projecting posterior edge could not have been greatly extended. Construing the structure thus given from a relief of the natural dorsal mold we note in addition to the midrib a low submarginal ridge on each side which anteriorly impresses the segments in such a way as to thicken each but posteriorly produces only a sinuosity in the outline of the plates which is doubtless intensified by the breaking away of the edges of the plates themselves. Besides these there are obscure traces of other longitudinal lines. The posterior extremity of the body is blunt but the anterior end tapers narrowly and in some of the specimens terminates in a smooth blunt subcylindric process which resembles what the head should apparently be in such an organism.

Along the lateral margins are broad free fringes like matted bunches of setae which may attain a length of nearly or quite half the width of the body. All the specimens show this character but in one only do these present the aspect of a continuation near the posterior extremity of the edges of the dorsal scutes. One could conceive the thickenings of the margin by the submarginal ridges as due to the parapodia.

The marginal filaments are usually directed backward, though they may turn forward toward the anterior extremity.

The cast of the other, or ventral surface simply presents these various details of structure with some obscurity.

These characters seem throughout so suggestive of the features shown by Aphrodite and Polynoe that we shall probably not be far amiss in associating these forms therewith; if not in direct association, at least with the Errant worms. For a designation therefore, we propose to indicate these objects as Protonympha salicifolia.

2 The second series of these annelids is composed of much more elongate bodies like Phyllodoce or Nereis and are usually curled up in spirals. These are rather blunt at one end, maintain a somewhat uniform width for most of their length but taper thence to a narrow extremity. The bodies are distinctly segmented, in the best preserved of the specimens there being upward of 100 narrow divisions which are separated from each other by tolerably deep depressions. In the axial line is a furrow which so divides the segments as to give each the appearance of being in two parts. It is not evident that these segments were plated but the impressions which they leave in sandy sediments seem to indicate this as a possible condition. Each however bears at each margin a parapodium carrying a bunch of long setae making a fringe often wider than the body itself, and into these parapodia the segments seem to extend without interruption. The general expression of this structure is very like that of the long row of posterior segments in Chaetopterus and there is also a notable similitude between the arrangement of the segments in the latter and that shown at the broad extremity of the fossil in question, and furthermore in the clear development of the median part represented by the axial line in

the fossil body. The single example of these worms which is not closely coiled has the body partly flattened and partly compressed laterally so as to bring the setae into profile, but the other specimens (three in number) are more or less closely coiled and their structure, save the bristles, is not as distinctly set forth. These all have a certain resemblance to Iulus and other myriapods and the fact of their occurrence in sands where comminuted remains of terrestrial vegetation have been freely accumulated, at first suggested this as their probable character, but the specimens do not on close examination reveal the structures of that group. This second group of worms may be designated as Palaeochaeta devonica.

Geologic horizon and localities. All these bodies occur in the sands, flags and shales which in the Naples (Ontario county) section lie immediately above the layers which carry the last representatives of the Intumescens fauna. These layers are locally known as the Hatch sands and carry very few fossils, Paropsonema cryptophyum, Orbiculoidea magnifica, a linguloid of peculiar aspect, Hydnoceras, with fragments of Lepidodendron and other plant remains. With one exception all are from the village of Naples, Ontario co. and Italy hill, 3 miles northeast in Yates county. A single example is from soft olive shales a few feet below the horizon of the Grimes sandstone, Grimes gully, Naples.

EXPLANATION OF PLATES

PLATE 1

Pentremites leda Hall

Page 907

1 The only example of this species observed. x3. Canandaigua lake, N. Y.

Paracyclas lirata Conrad *mut.* pygmaea *nov.*

Page 910

2, 3 Side and dorsal view. x13. Canandaigua lake, N. Y.

Nucleospira concinna *mut.* pygmaea *nov.*

[*See* pl. 2, fig. 5]

Page 904

4 Dorsal view of specimen figure 5, plate 2. x13. Greigsville N. Y.

Leda rostellata Hall *mut.* pygmaea *nov.*

Page 909

5 Dorsal view. x13. Canandaigua lake, N. Y.

6 Left valve. x13. Greigsville N. Y.

Nuculites oblongatus Conrad *mut.* pygmaeus *nov.*

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7 Cast of left valve. x8. Moscow N. Y.

Palaeoneilo plana Hall *mut.* pygmaea *nov.*

Page 909

8, 9 Views of an internal cast. x3. Livonia shaft, N. Y.

Nucula corbuliformis Hall *mut.* pygmaea *nov.*

Page 908

10, 11 Internal cast, dorsal and lateral views. x2. Livonia shaft, N. Y.

Palaeoneilo constricta Conrad *mut.* pygmaea *nov.*

Page 910

12, 13 Dorsal and left views of internal cast. x13. Moscow N. Y.

Nucula lirata Hall *mut.* pygmaea *nov.*

Page 908

14, 15 Oblique anterior and left lateral views. x13. Livonia shaft, N. Y.

Nuculites triqueter Conrad *mut.* pygmaeus *nov.*

Page 909

16, 17 Right and dorsal aspects of an internal cast. x13. Moscow N. Y.

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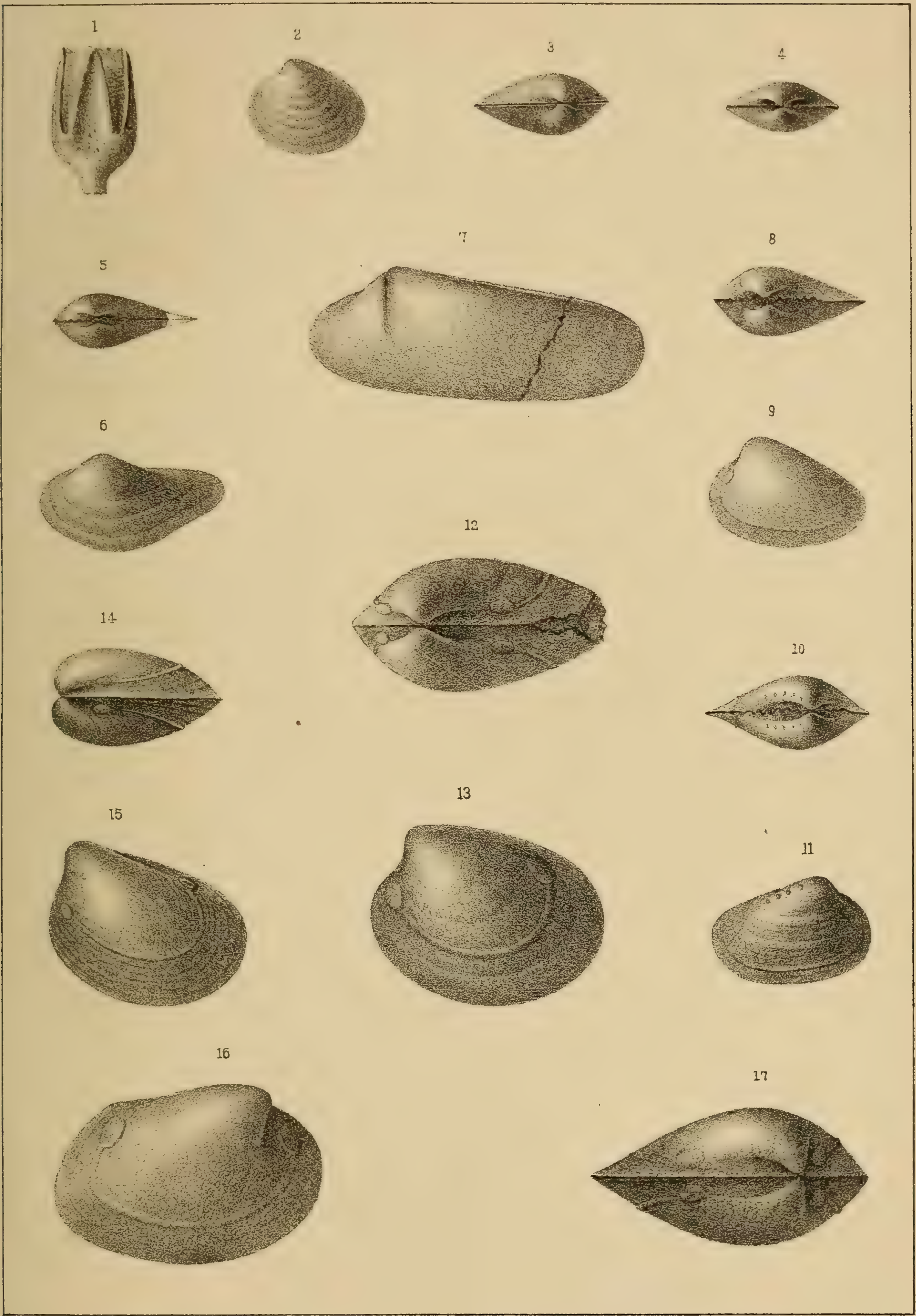

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PLATE 2

Grammysia constricta Hall *mut.* pygmaea *nov.*

Page 910

1, 2 Dorsal and right aspects of a cast. x13. Greigsville N.Y.

Nucula varicosa Hall *mut.* pygmaea *nov.*

Page 908

3, 4 An incomplete cast. x13. Greigsville N. Y.

Nucleospira concinna Hall *mut.* pygmaea *nov.*

[*See* pl. 1, fig. 4]

Page 904

5 An internal cast. x13. Greigsville N. Y.

Conocardium eboraceum Hall *mut.* pygmaeum *nov.*

Page 911

6 Dorsal view. x4. Moscow N. Y.

Buchiola retrostriata v. Buch *mut.* pygmaea *nov.*

Page 911

7 Right valve. x3. Moscow N. Y.

Spirifer fimbriatus Conrad *mut.* pygmaeus *nov.*

Page 901

8, 9 Dorsal and ventral views. x13. Canandaigua lake, N. Y.

Strophalosia truncata Hall *mut.* pygmaea *nov.*

Page 906

10, 12 Dorsal (x5) and ventral (x13) valves. Canandaigua lake, N. Y.

Productella spinulicosta Hall *mut.* pygmaea *nov.*

Page 907

11 Ventral valve. x4. Canandaigua lake, N. Y.

Ambocoelia umbonata Conrad *mut.* pygmaea *nov.*

Page 905

13–15 Posterior, dorsal and ventral views. x13. Canandaigua lake, N. Y.

Ambocoelia umbonata Conrad *mut.* pluto *nov.*

Page 905

16–18 Ventral, profile and dorsal views. x13. Canandaigua lake, N. Y.

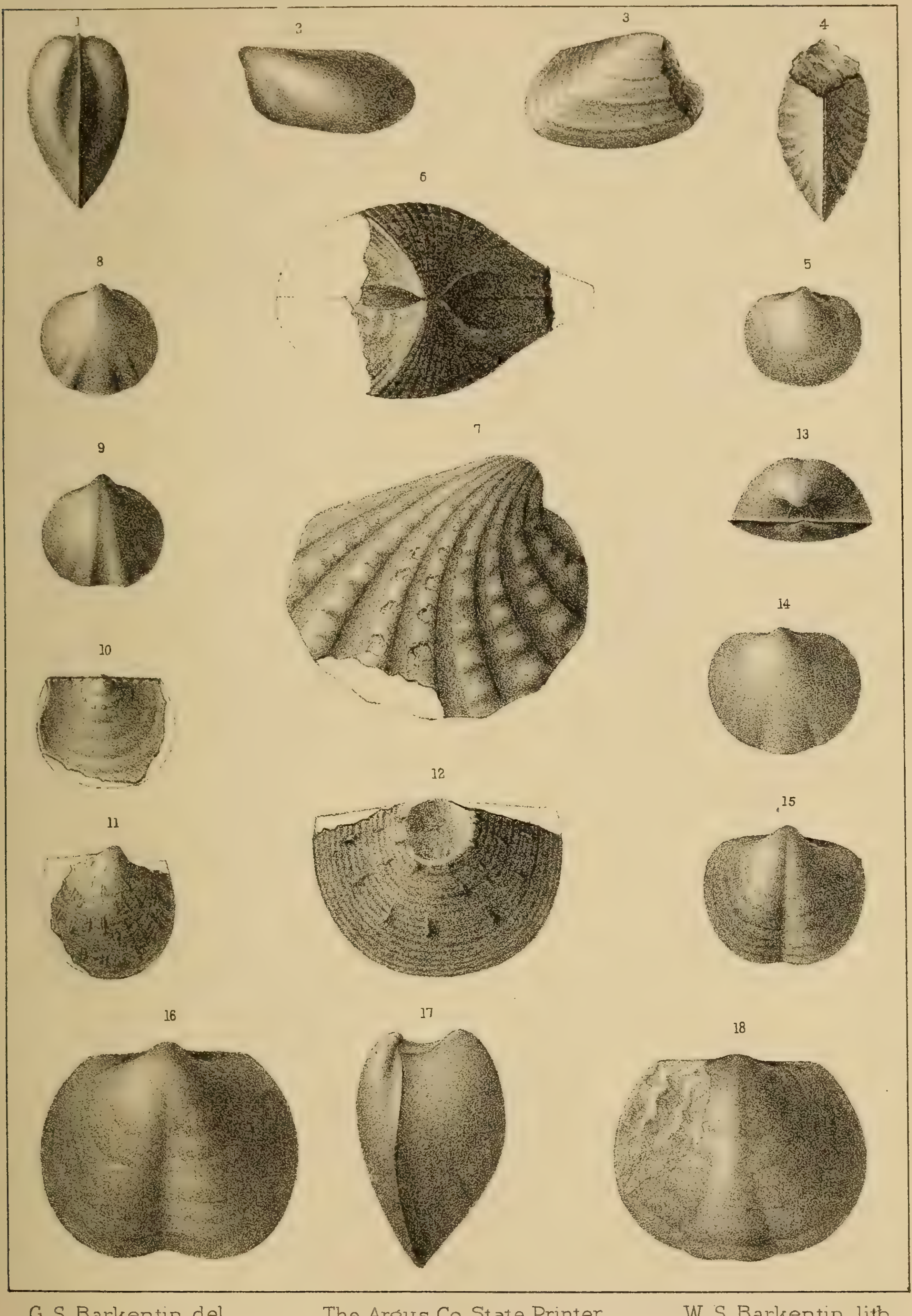

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PLATE 3

Spirifer fimbriatus *mut.* **simplicissimus** *nov.*

Page 901

1, 2 Dorsal and ventral valves. x13. Canandaigua lake, N. Y.

Spirifer tullius Conrad *mut.* **belphegor** Clarke

Page 903

3, 4 Dorsal and ventral views. x8. Canandaigua lake, N. Y.

Spirifer marcyi Hall *mut.* **pygmaeus** *nov.*

Page 904

5, 6 Ventral and dorsal views. x8. Moscow and Canandaigua lake, N. Y.

Spirifer granulosus Conrad *mut.* **pluto** Clarke

Page 903

7, 8 Posterior and ventral views. x13. Canandaigua lake, N. Y.

Spirifer medialis Hall *mut.* **pygmaeus** *nov.*

Page 902

9, 10 Posterior and ventral views. x13. Canandaigua lake, N. Y.

Trigeria lepida Hall *var.* **pygmaea** *nov.*

Page 907

11 Ventral aspect. x13. Canandaigua lake, N. Y.

Tropidoleptus carinatus Conrad *mut.* **pygmaeus** *nov.*

Page 906

12 Ventral aspect. x8. Canandaigua lake, N. Y.

Spirifer mucronatus Con. *mut.* **hecate** Clarke

Page 902

13–15 Posterior, dorsal and ventral views. x13. Moscow N. Y.

Cyrtina hamiltonensis Hall *mut.* **pygmaea** *nov.*

Page 904

16 Dorsal valve. x13. Canandaigua lake, N. Y.

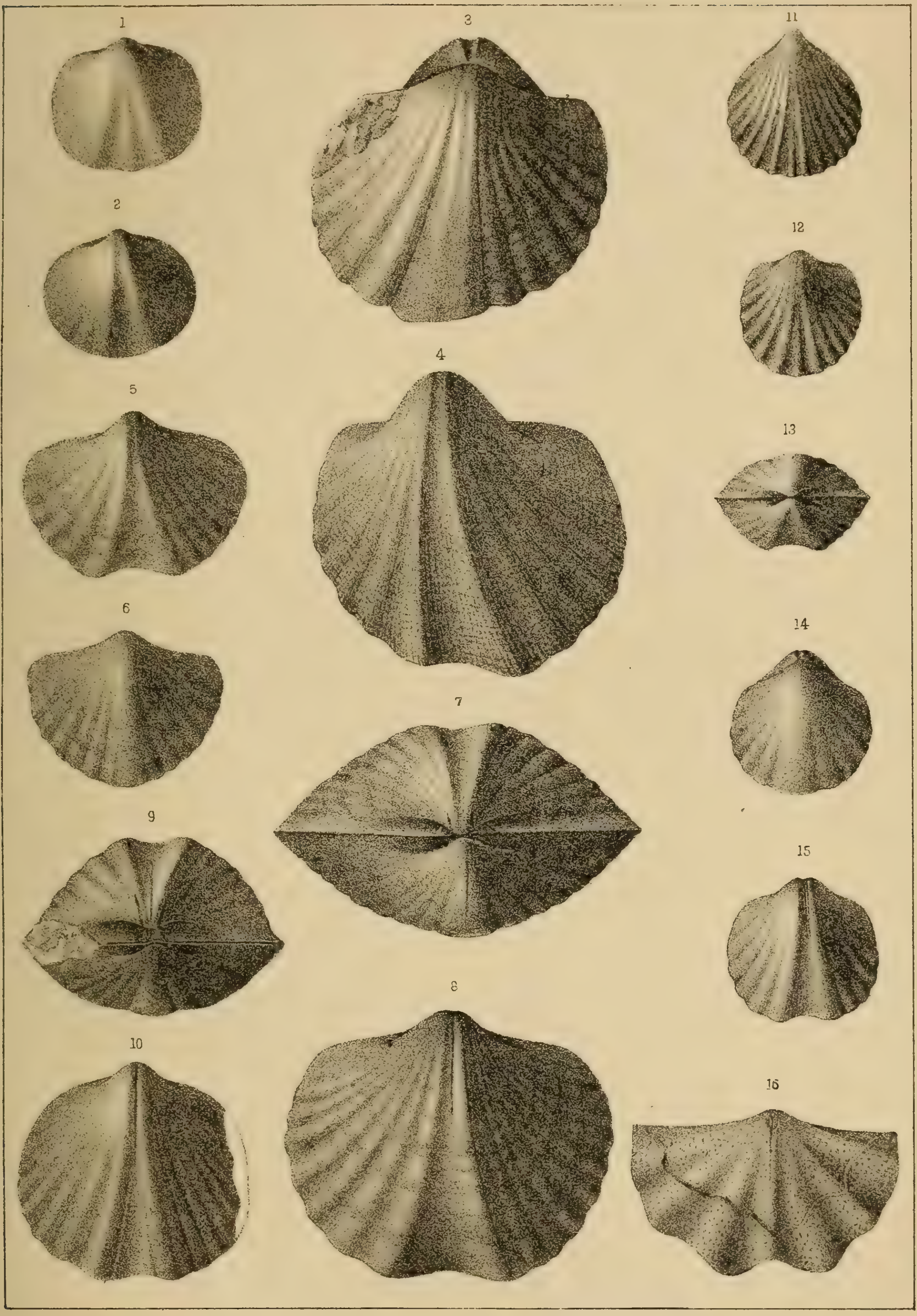

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PLATE 4

Macrochilina hamiltoniae *mut.* **pygmaea** *nov.*

Page 912

1 An internal cast. x13. Moscow N. Y.

Diaphorostoma (?)

2, 3 Apical and lateral views. x13. Canandaigua lake, N. Y.

Macrochilina hebe Hall *mut.* **pygmaea** *nov.*

Page 912

4 Lateral view. x13. Moscow N. Y.

Pleurotomaria itys Hall (?) *mut.* **pygmaea** *nov.*

Page 913

5 Lateral view. x13. Canandaigua lake, N. Y.

Pleurotomaria capillaria Conrad *mut.* **pygmaea** *nov.*

Page 912

6 Lateral view. x13. Canandaigua lake, N. Y.

Diaphorostoma (?)

7, 8 Views of shells whose specific relations are uncertain. x25. Canandaigua lake, N. Y.

Diaphorostoma lineatum Conrad *mut.* **belial** Clarke

Page 911

9 Lateral view. x13. Canandaigua lake, N. Y.

Loxonema delphicola Hall *mut.* **moloch** Clarke

Page 913

10 A fragment. x3. Moscow N. Y.

Tentaculites gracilistriatus Hall *mut.* **asmodeus** Clarke

Page 913

11 A view of the shell. x13. Livonia shaft, N. Y.

Bactrites? *sp. mut.* **pygmaeus** *nov.*

Page 915

12, 13 Two views of an internal cast. x13. Canandaigua lake, N. Y.

Orthoceras scintilla Hall (?) *mut.* **mephisto** Clarke

Page 915

14 Lateral and septal views. Natural size. Canandaigua lake, N. Y.

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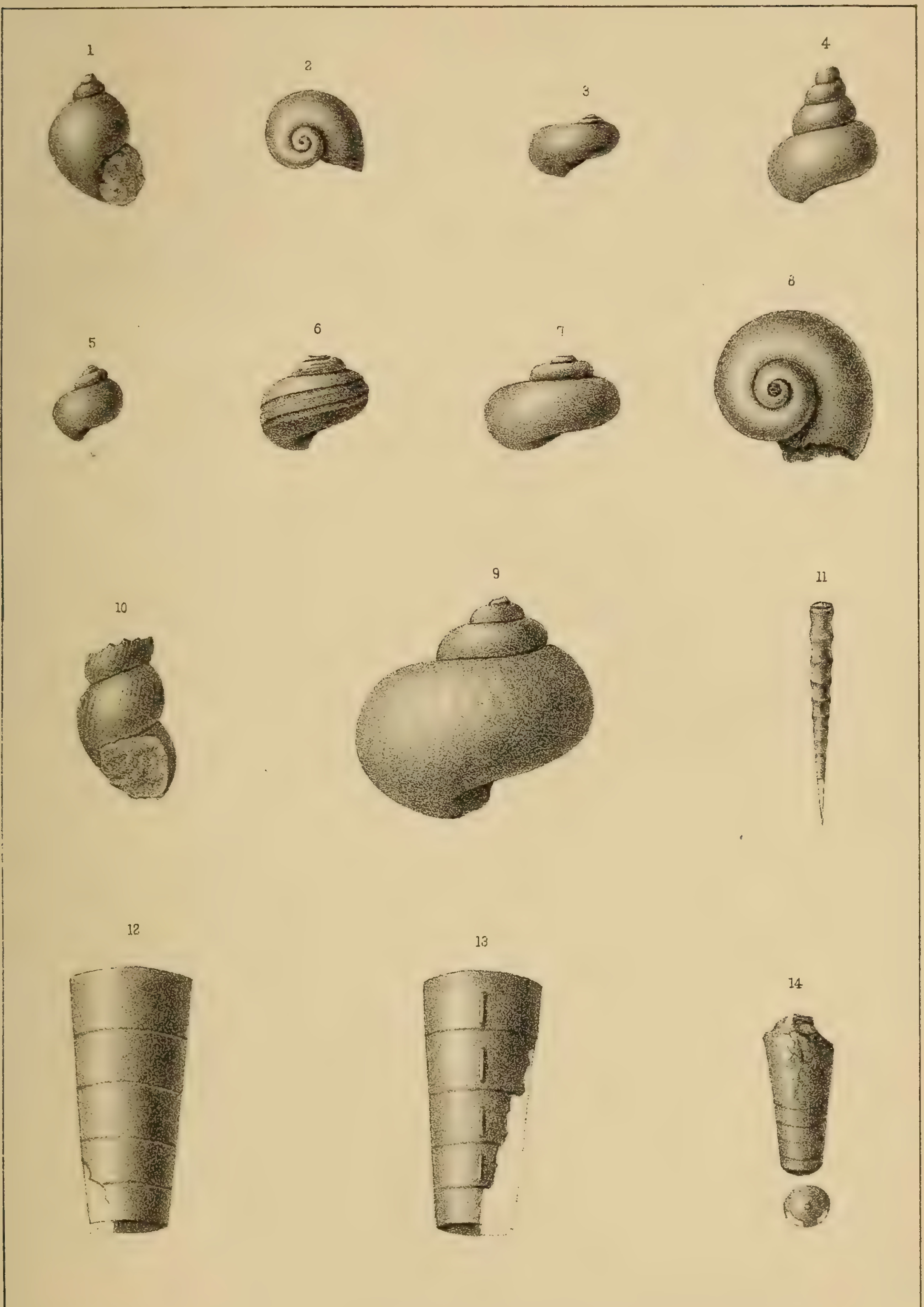

G. S. Barkentin. del. The Argus Co., State Printer. W. S. Barkentin lith.

PLATE 5

Tornoceras uniangulare Conrad *mut.* **astarte** Clarke

Page 916

1, 2 Lateral views of two specimens. x13 and x8. Livonia shaft and Canandaigua lake, N. Y.

Tornoceras uniangulare Conrad

Page 916

3 Lateral view. x3. Canandaigua lake, N. Y.

Bactrites (*sp.* ?) *mut.* **parvus** *nov.*

Page 916

4, 5 Lateral and septal views. x3. Canandaigua lake, N. Y.

Orthoceras subulatum Conrad *mut.* **pygmaeum** *nov.*

Page 914

6, 7 Lateral and septal views. x13. Canandaigua lake, N. Y.

Tentaculites bellulus (?) *mut.* **stebos** Clarke

Page 914

8 Lateral view of a fragment. x13. Livonia shaft, N. Y.

Orthoceras nuntium Hall

Page 915

9 Lateral view of a specimen. Natural size. Canandaigua lake, N. Y.

Entomis prosephina *nov.*

Page 918

10, 11 Ventral and lateral views. x13. Canandaigua lake, N. Y.

Beyrichia dagon Clarke

Page 918

12–14 Lateral, dorsal and ventral views. x13. Greigsville N. Y.

Cryphaeus boothi *var.* **calliteles** Green

Page 917

15 A fragment of head and thorax. x7. Moscow N. Y.

PYRITE FAUNA

Rep Paleontologist 1902 Plate 5

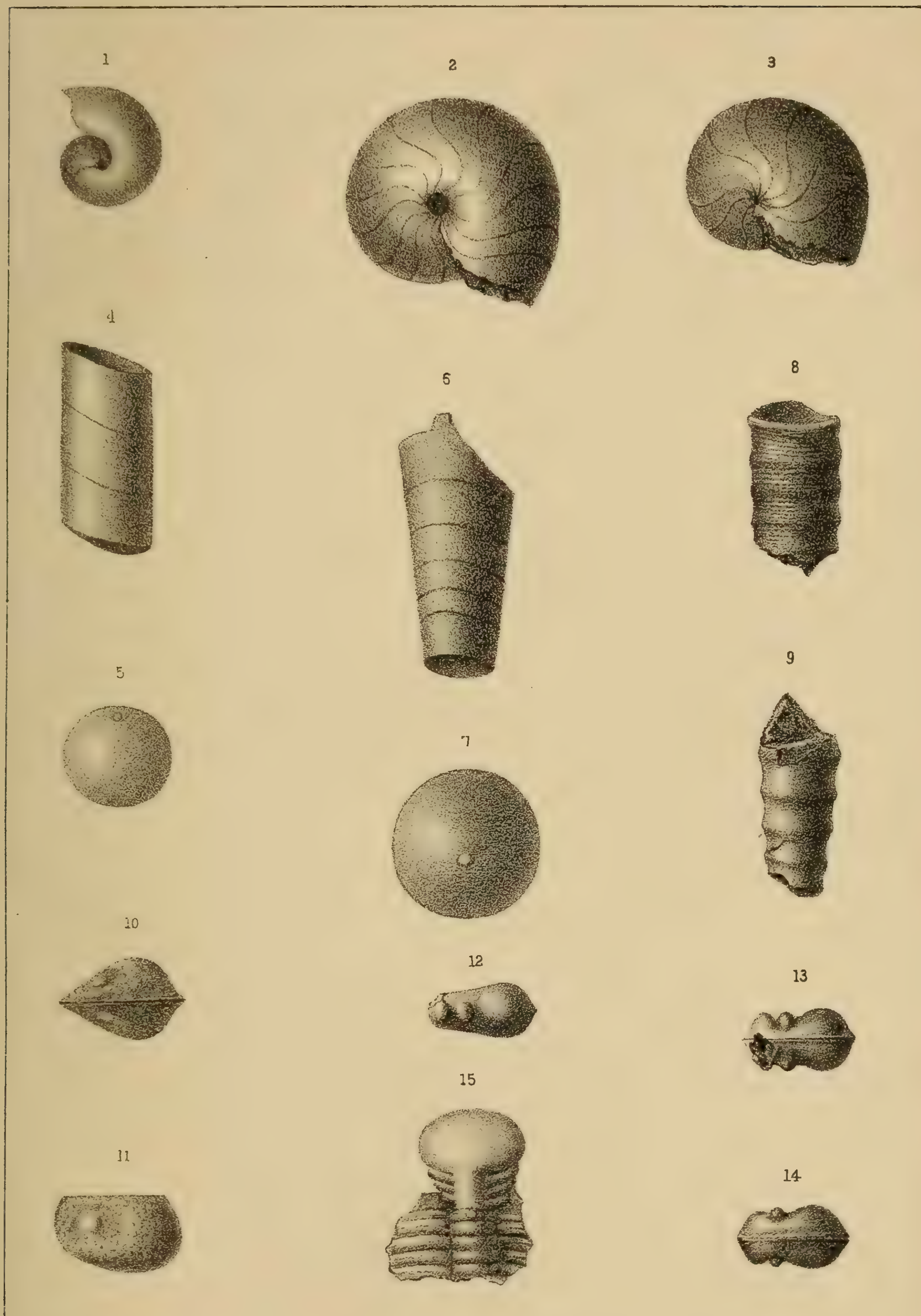

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PLATE 6

Hughmilleria socialis *sp. nov.*

Page 1091

1 Dorsal view of specimen below average size retaining the swimming feet. Shows compound eyes and ocelli. Natural size

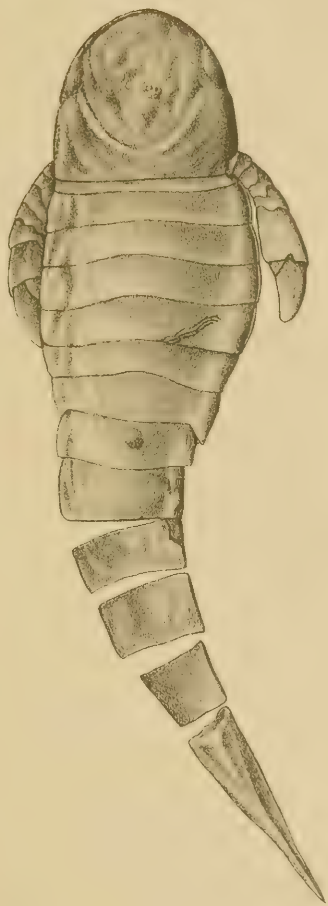

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PLATE 7

Hughmilleria socialis ***sp. nov.***

Page 1091

1 Dorsal view of average individual with a fragmentary preoral appendage and a nearly perfect endognathite. **Shows** ocelli and ocelliferous tumescence. Natural size

Rep. Paleontologist 1902. Plate 7

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PLATE 8

Hughmilleria socialis *sp. nov.*

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1 Ventral view of well preserved specimen. Shows the extended right preoral appendage, three endognathites of the right side (left in drawing) with their coxal joints in position, the mouth, the metastoma, the gnathobases in position, the left swimming foot, male operculate appendage and the imbricating surface scales. The postlateral extensions of the first postabdominal ring are also well shown. Natural size

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PLATE 9

Hughmilleria socialis *sp. nov.*

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1 Dorsal view of a large specimen. The anterior portion of the cephalothorax is broken away and there is thereby exposed one extended preoral appendage and the endognathites of the right side. Both swimming feet are also shown. Natural size

CRUSTACEA

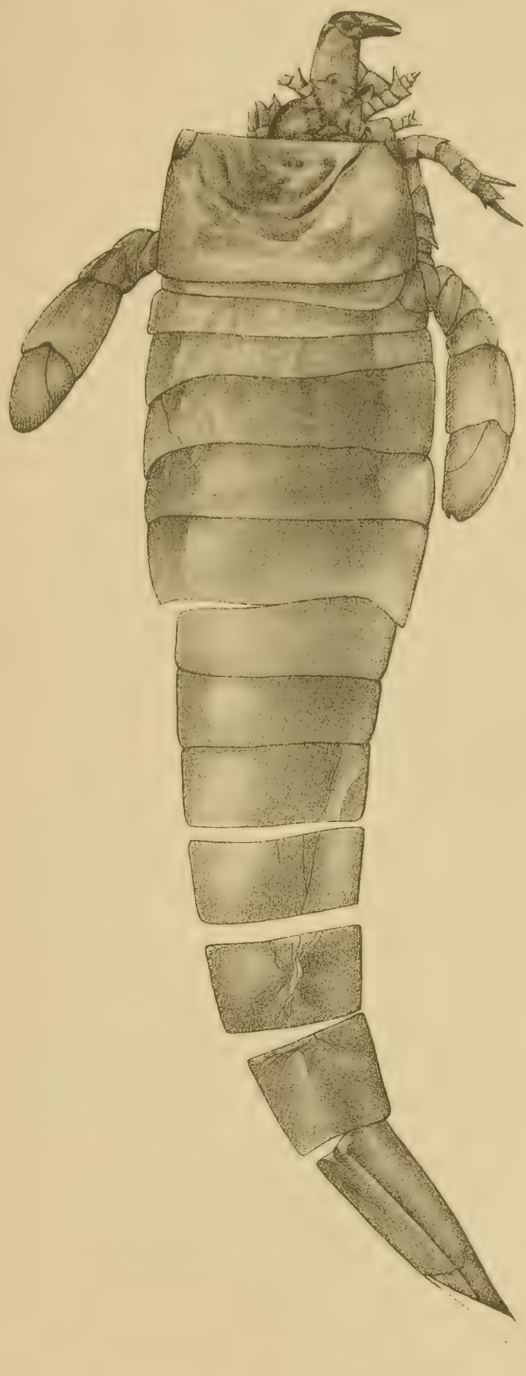

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PLATE 10

Hughmilleria socialis *sp. nov.*

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1-6 Cephalothoraces of individuals of various ages, showing slight variations in outline and in the position of compound eyes. Natural size

Eurypterus pittsfordensis *sp. nov.*

Page 1098

7 Upper view of appendages of cephalothorax. Shows the endognathites in position, with their clawlike terminal joints, and the gnathobases of the swimming feet. Natural size

Hughmilleria socialis *sp. nov.*

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8 Two gnathobases of swimming feet. Natural size

9 Coxal joint of endognathite. x3

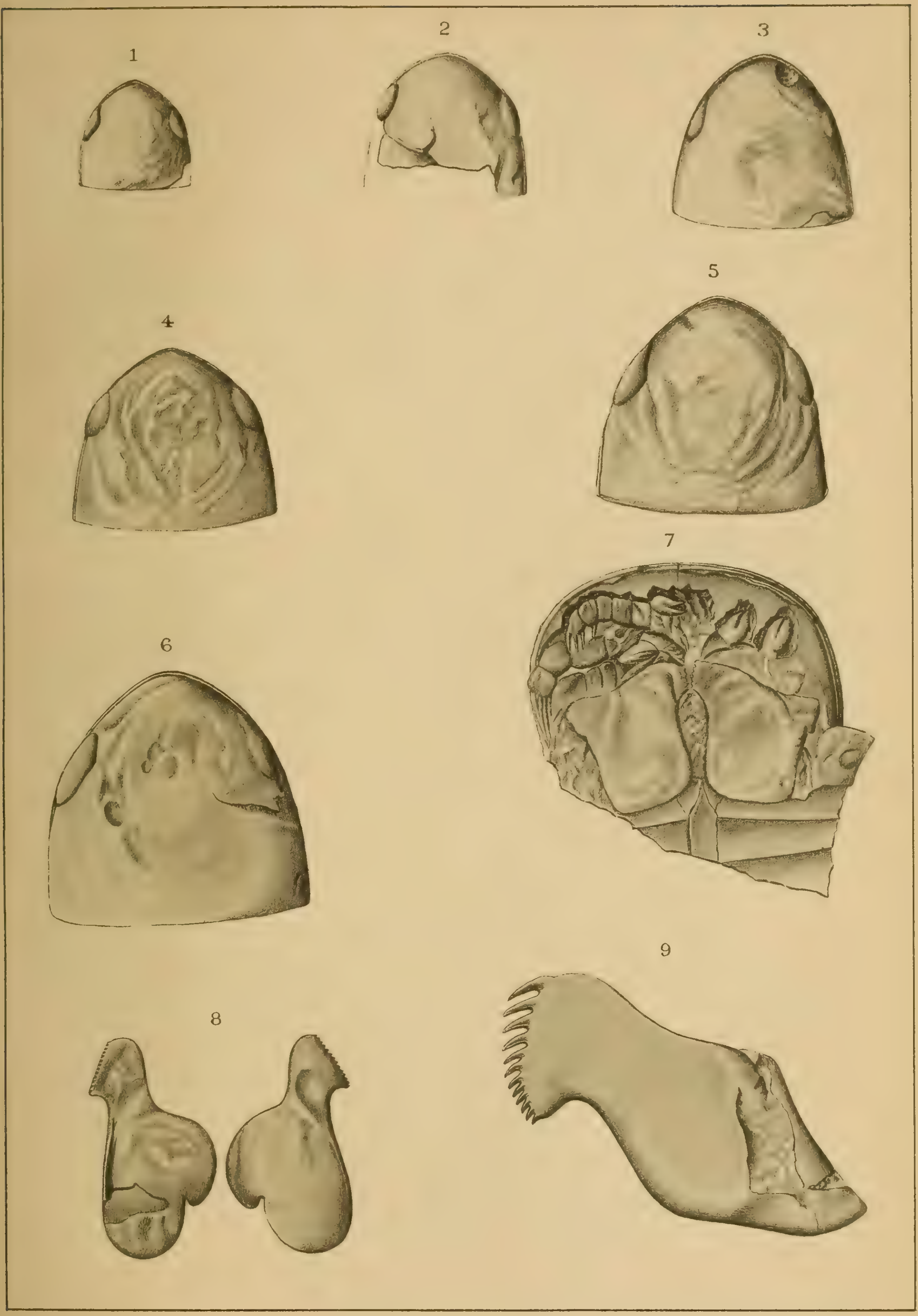

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PLATE 11

Hughmilleria socialis *sp. nov.*

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1 Dorsal view of right side of cephalothorax with the four endognathites in position. x3

2 Extended preoral appendage and first two pairs of endognathites. x3

3 Pair of preoral appendages, supposedly in normal position. x3

4, 5 Preoral appendages showing variations in relative form of the pincers. Figure 4, x4; figure 5, x3½

6 Ventral view of anterior end of cephalothorax, showing the preoral appendages turned back full length, their tips lying over end of metastoma. Natural size

7 Complete preoral appendage in natural position. x3½

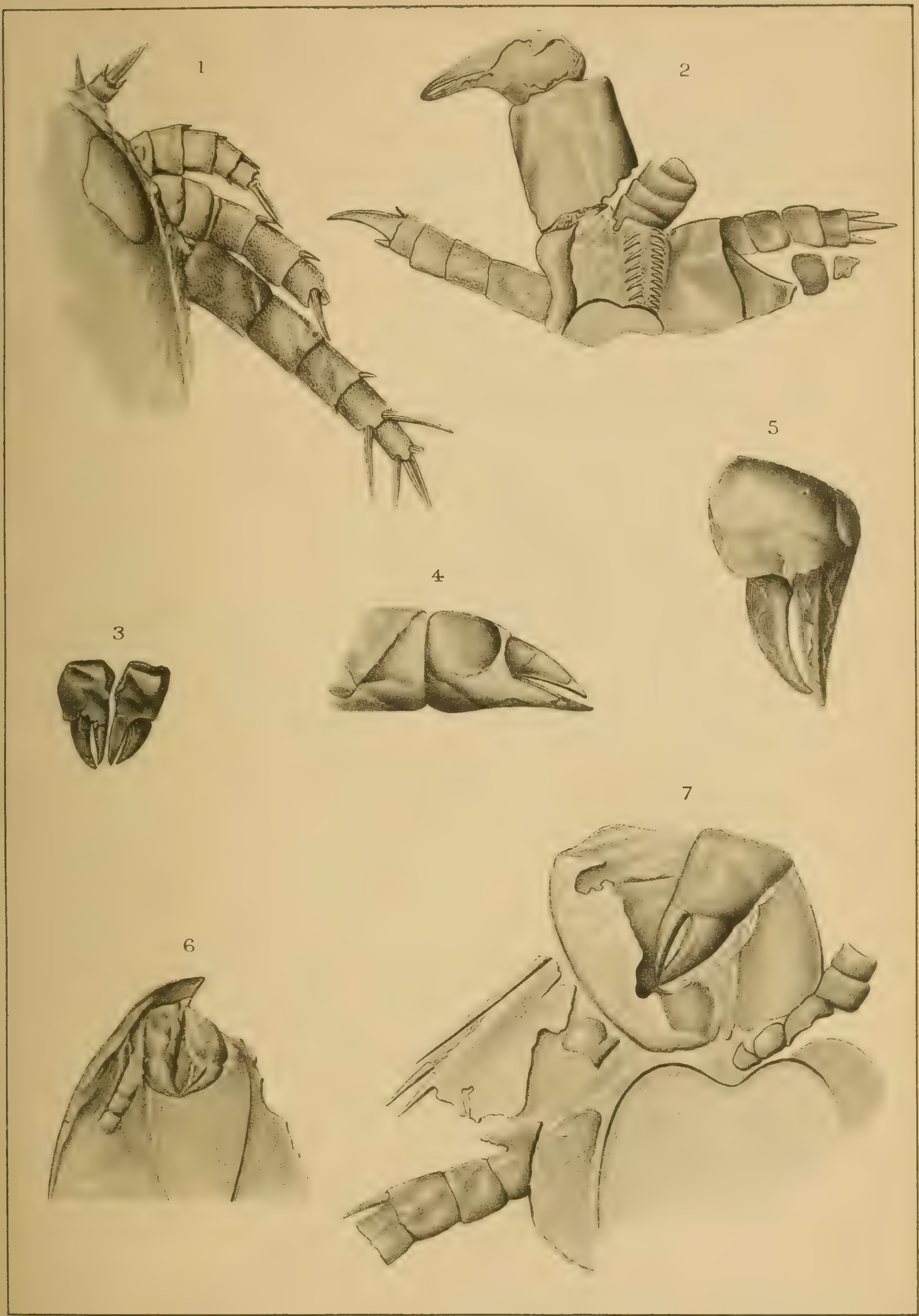

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PLATE 12

Hughmilleria socialis ***sp. nov.***

Page 1091

1 The two posterior endognathites in perfect preservation; and fragments of the two anterior ones. Drawing inverted. x3

2 Anterior portion of cephalothorax showing dehiscence of epistoma through middle and the anterior ends of the gnathobases. x3½

3 Complete swimming foot. x3

4 Complete endognathite showing coxal joint, articulation of second joint and lobe of sixth joint. x3½

6, 7 Two metastomata, showing slight variation in form. Natural size

8 Section which shows cylindric form of postabdomen. Natural size

Dolichopterus ? ?

5 Metastoma of an undetermined form. x3½

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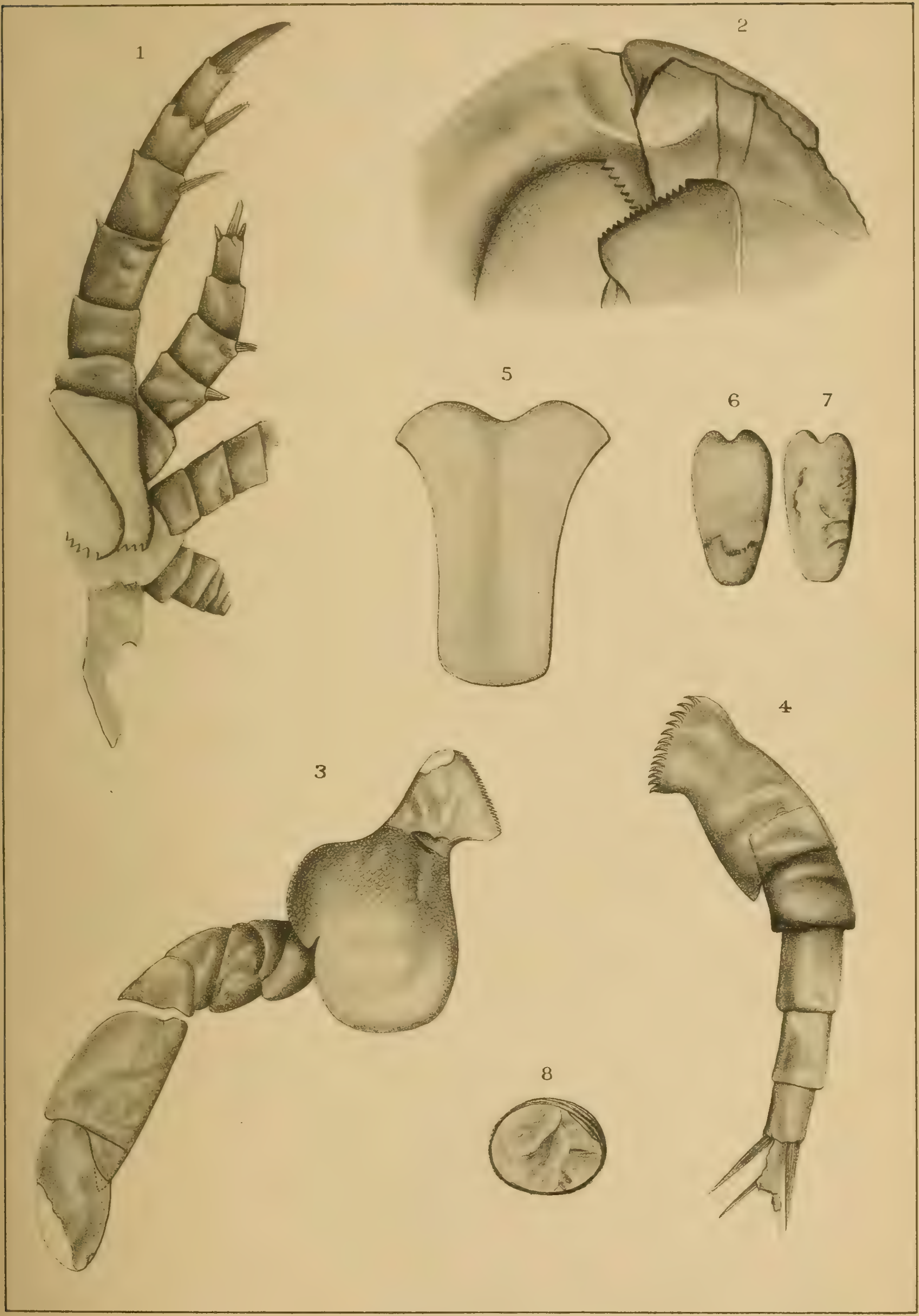

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PLATE 13

Hughmilleria socialis *sp. nov.*

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1 Middle portion of operculum and second sternite, to show female genital appendages. Shows partial covering of appendage of second sternite by opercular appendage. This second appendage should have been drawn so as to give a more elongate, tubular appearance. x3½

2 Same as preceding, showing appendage of second sternite fully exposed. The longitudinal groove shown on this appendage is the result of pressure against the overlapped edges of the right and left halves of the sternite. x3½

3 View of male operculum and second sternite, showing male opercular appendage. x3½

4 Middle portion of operculum and second sternite showing fused parts of female opercular appendage and lanceolate shape of appendage of second sternite seen from inside of body. x2

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Rep. Paleontologist 1902. Plate 13

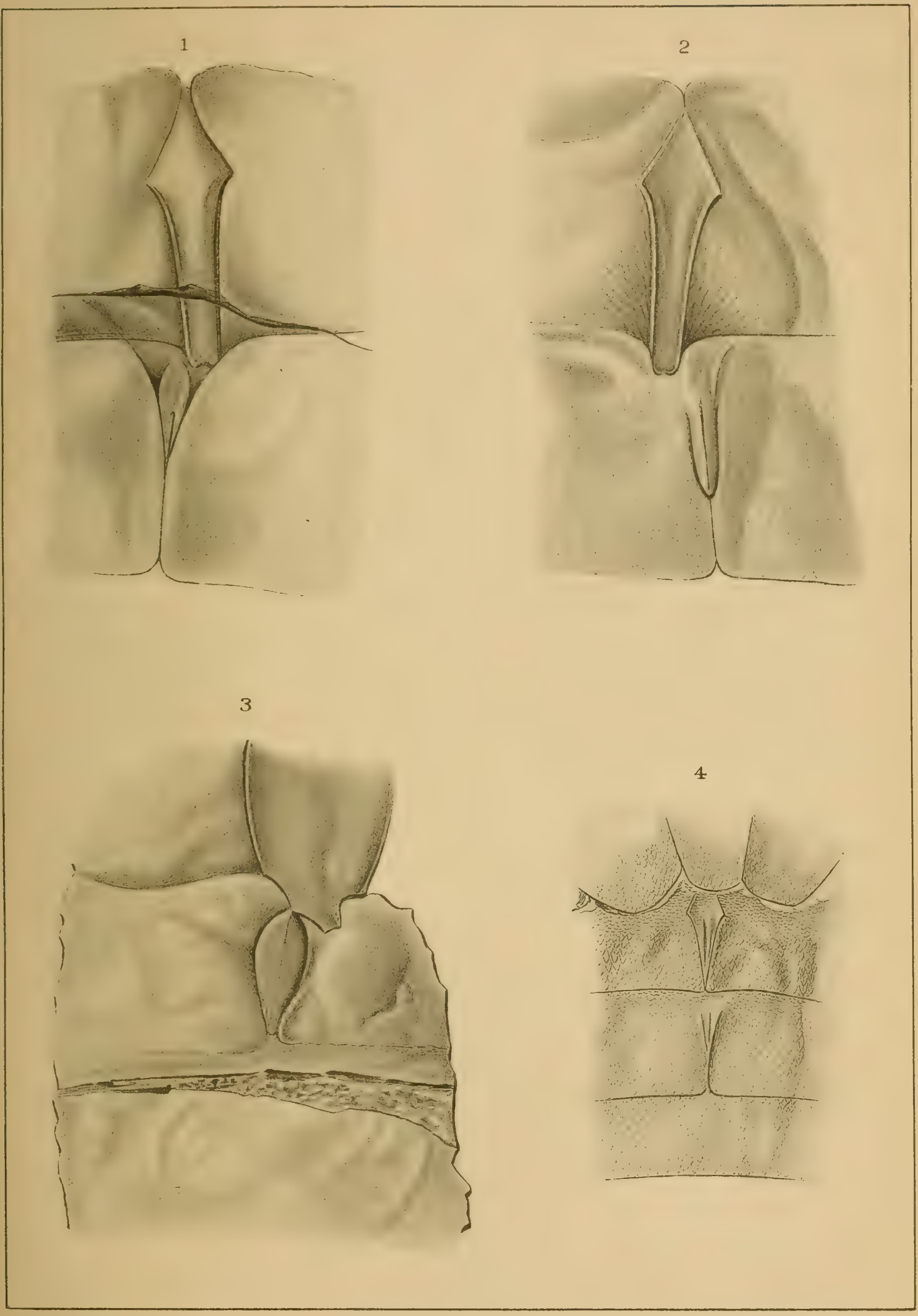

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PLATE 14

Hughmilleria socialis *sp. nov.*

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1 Male genital appendage, a portion of which is scaled away, giving a cast of the interior. x3½

2 Female genital appendage of second sternite, showing its partial covering by opercular appendage. x2½

3 Half operculum with attached female operculate appendage. Natural size

4 Half of female operculum showing face of median cleft. Natural size

5 Half of male operculum showing face of median cleft. Natural size

6 First postabdominal ring segment. Natural size

7 Second tergite showing the anterolateral lobe. Natural size

8 Fragment of seventh joint of swimming foot, showing group of minute craterlike tumescences. x4

9 First two sternites showing male appendage from the inside of body. x2

10 Middle portion of first two sternites to show female genital appendages, the overlap of the metastoma on the opercular appendage and that of the latter on the next appendage. x2

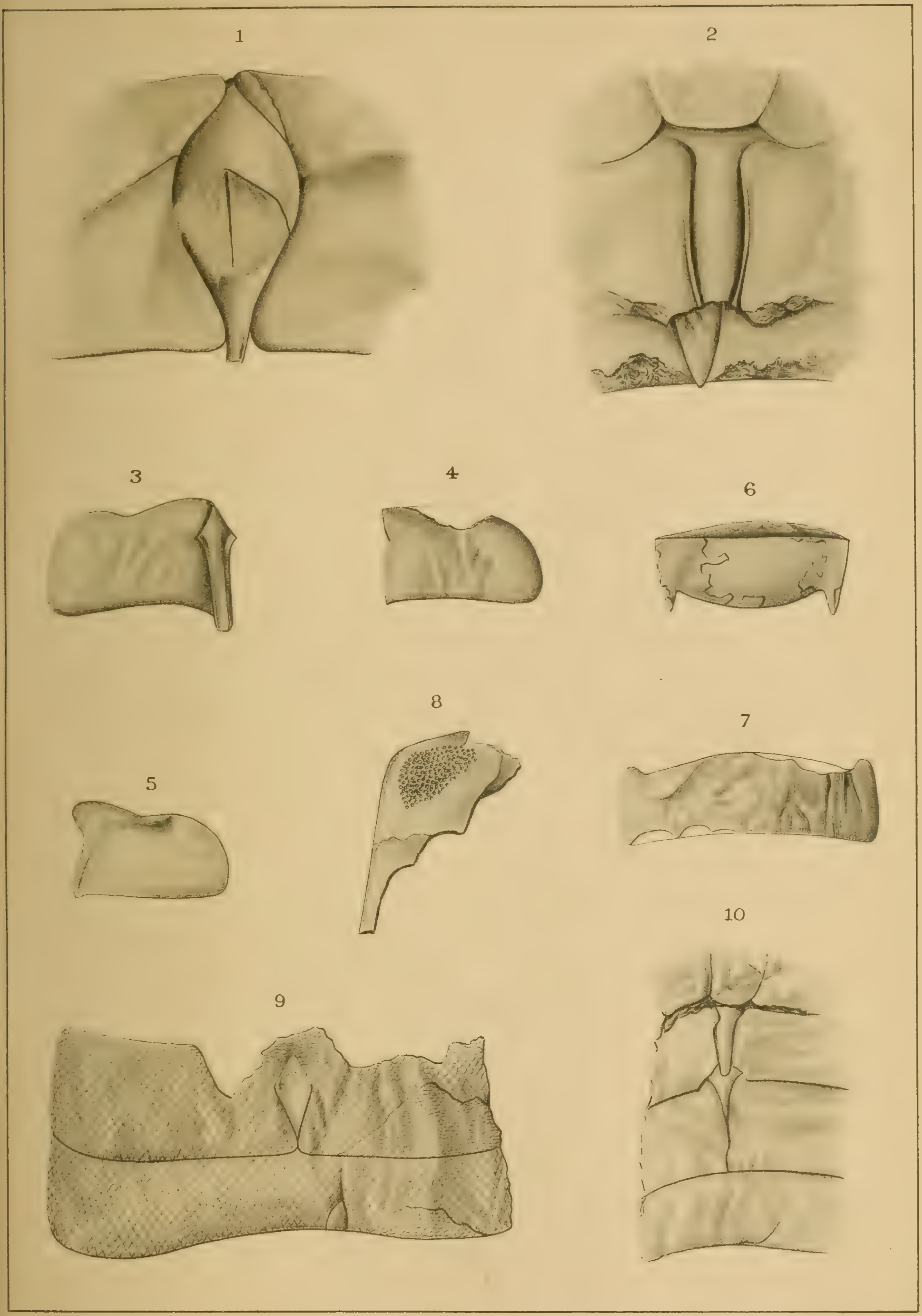

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PLATE 15

Eurypterus pittsfordensis *sp. nov.*

Page 1098

1 Gnathobase. Natural size

2. Half of sternite showing transversal suture and cleft

3 Portion of endognathite doubtfully referred to this species, probably fourth endognathite

Hughmilleria socialis *sp. nov.*

Page 1091

4, 5 Two views of telsons, showing the dorsal carination. Figure 4, x2; figure 5, x3½

6 Uncompressed telson. x2

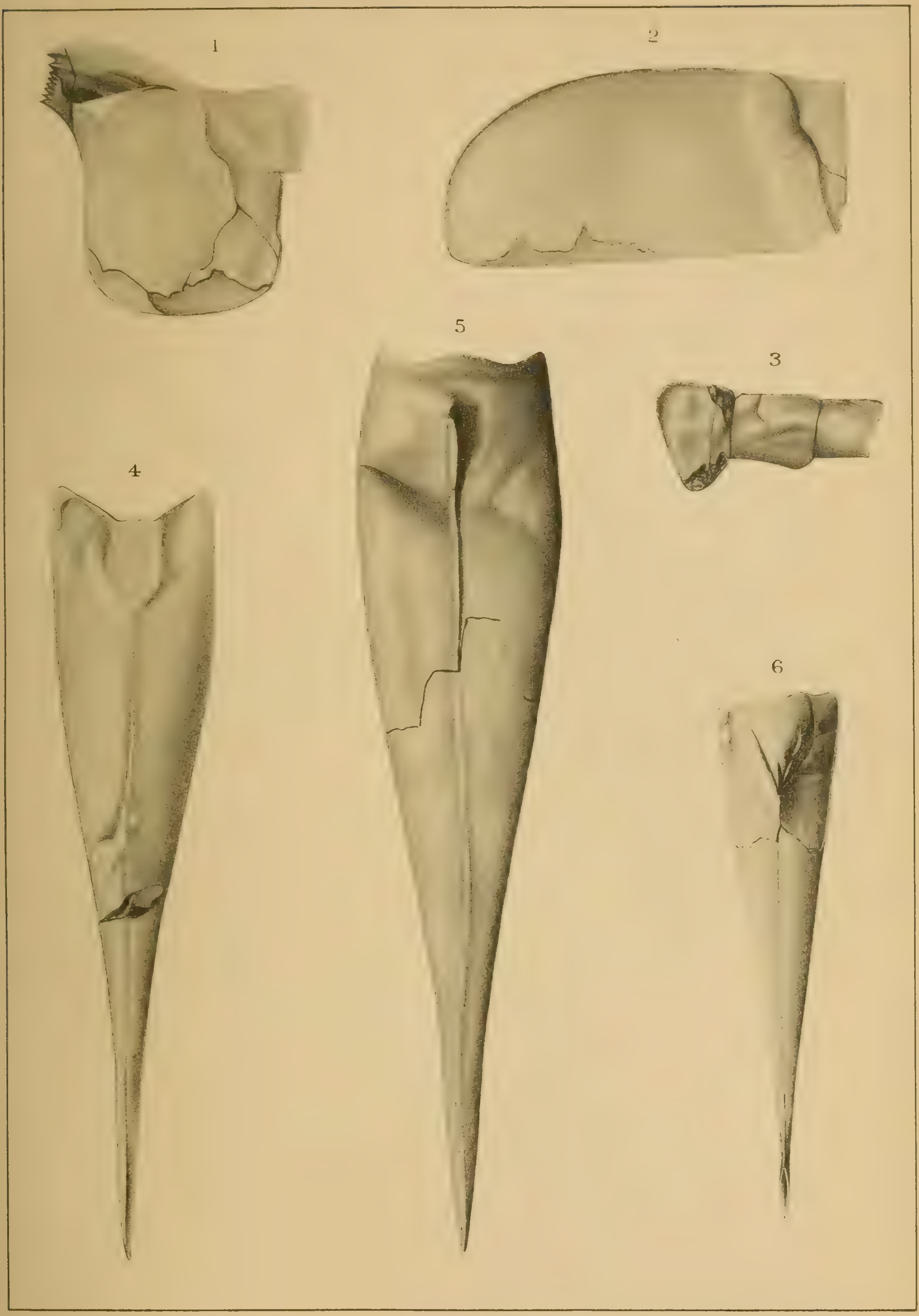

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PLATE 16

Eurypterus pittsfordensis *sp. nov.*

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1 Broken cephalothorax and portion of preabdomen showing two endognathites with their coxal joint in position, metastoma and a sternite; and view from the interior of the operculum and male appendage. Natural size

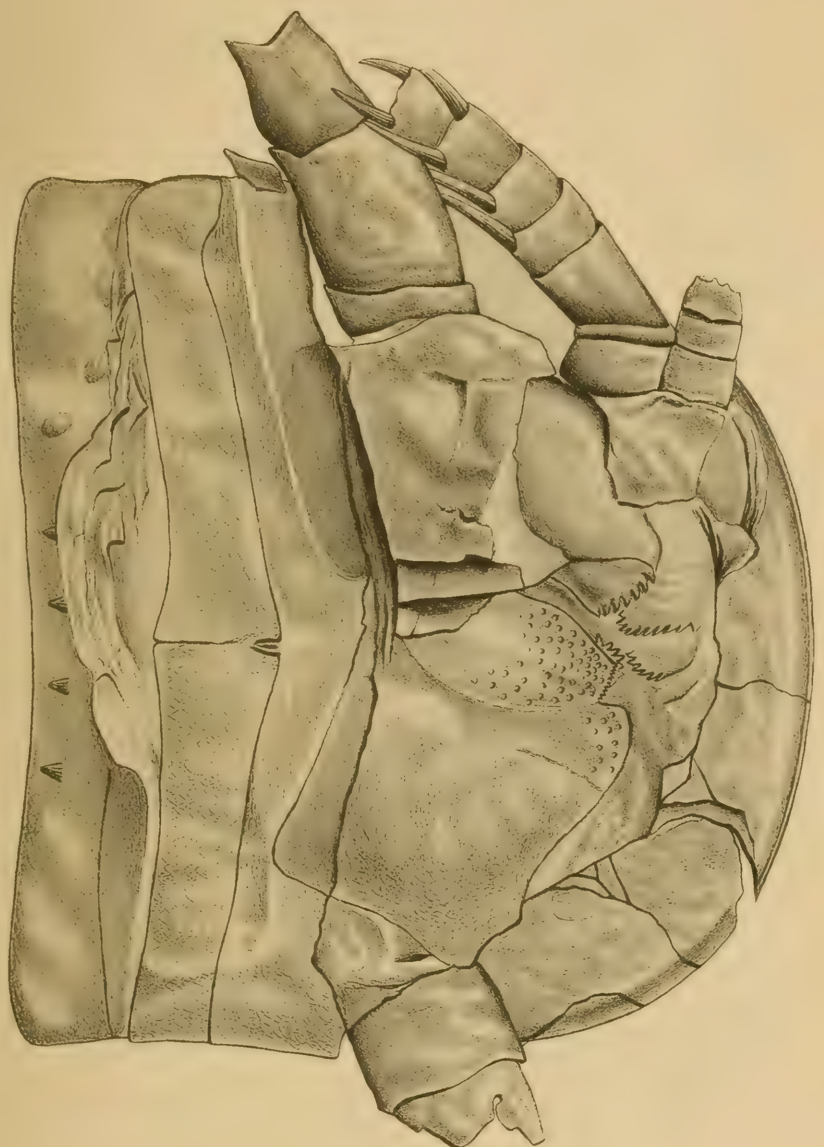

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PLATE 17

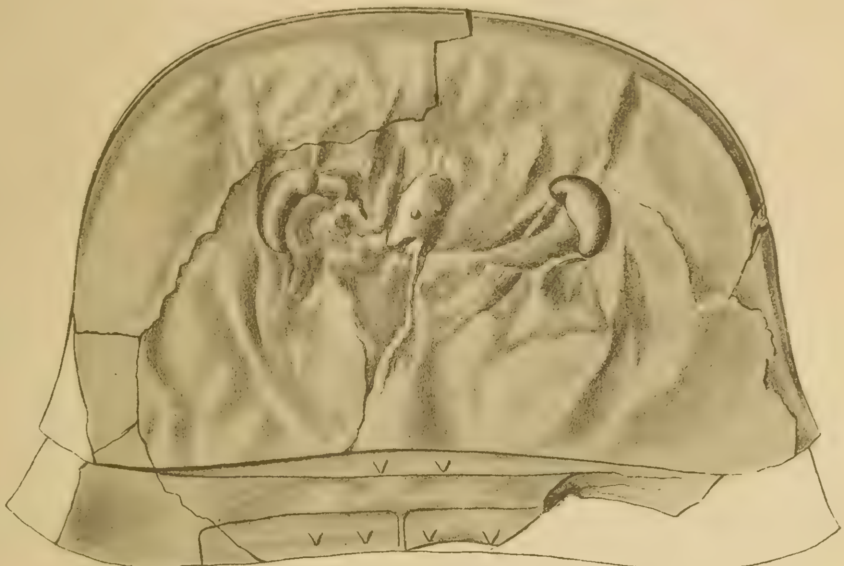
Eurypterus pittsfordensis *sp. nov.*

Page 1098

1 Cephalothorax and first tergite of average specimen showing compound eyes, ocelli and the two triangular scales at base of cephalothorax. Natural size

2 Coxa. x4

1



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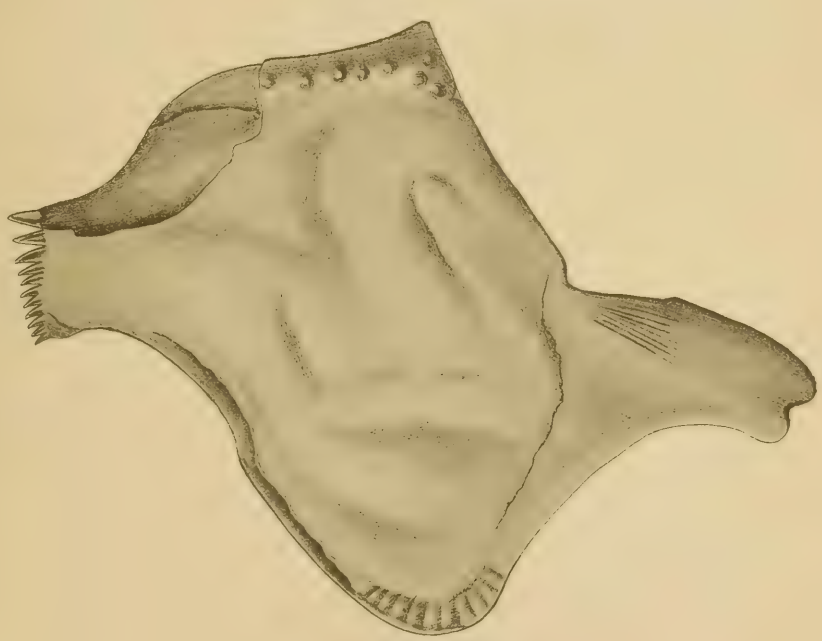

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PLATE 18

Eurypterus pittsfordensis *sp. nov.*

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1 Cephalothorax, preabdomen and two postabdominal rings. Shows eyes, ocelliferous tumescence; scales and surface sculpture of tergites and the posterolateral lobes of the postabdominal segments. Natural size

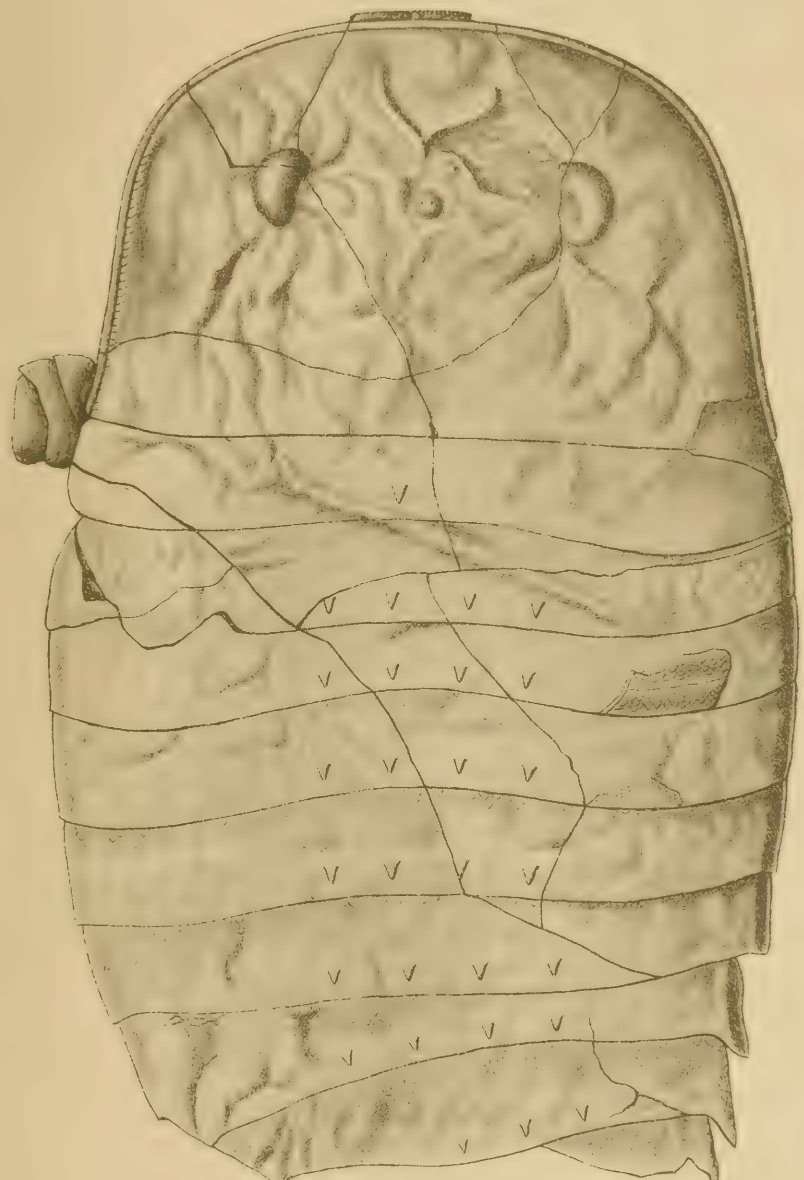

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PLATE 19

Eurypterus pittsfordensis *sp. nov.*

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1 Fragmentary abdomen. Shows character of tergites, notably their relative shortness and the four triangular scales on each preabdominal and on the first two postabdominal ring segments, while the succeeding two show their ventral characters. The swimming foot is also partially shown. Natural size

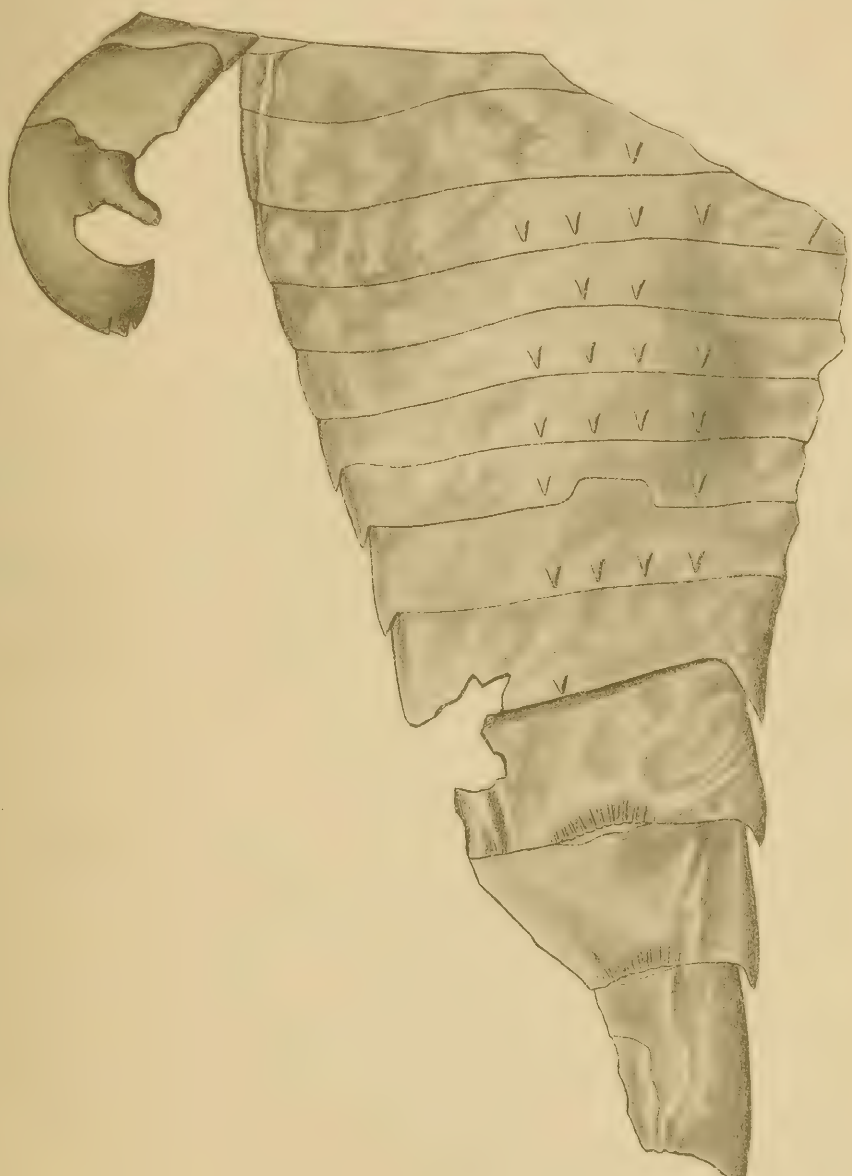

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PLATE 20

Eurypterus pittsfordensis *sp. nov.*

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1 Ventral view of part of last sclerite showing posterior emargination and curved rents. Natural size

2 Dorsal view of last sclerite showing the posterolateral striated spurs and the median denticulate notch of the posterior edge. Natural size

3 View of two sclerites and telson in approximate positions. Natural size

4 Ventral view of nearly complete telson. Natural size

5 Ventral view of proximal portion of telson. Natural size

6 Dorsal view of nearly complete telson. Natural size

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PLATE 21

Hughmilleria socialis *sp. nov. var.* **robusta** *var. nov.*

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1 Fragment of carapace showing relatively great width and abrupt postabdominal contraction. Natural size

2 First ring segment showing division of its posterior edge into two lobes. Natural size

3 Incomplete metastoma. Natural size

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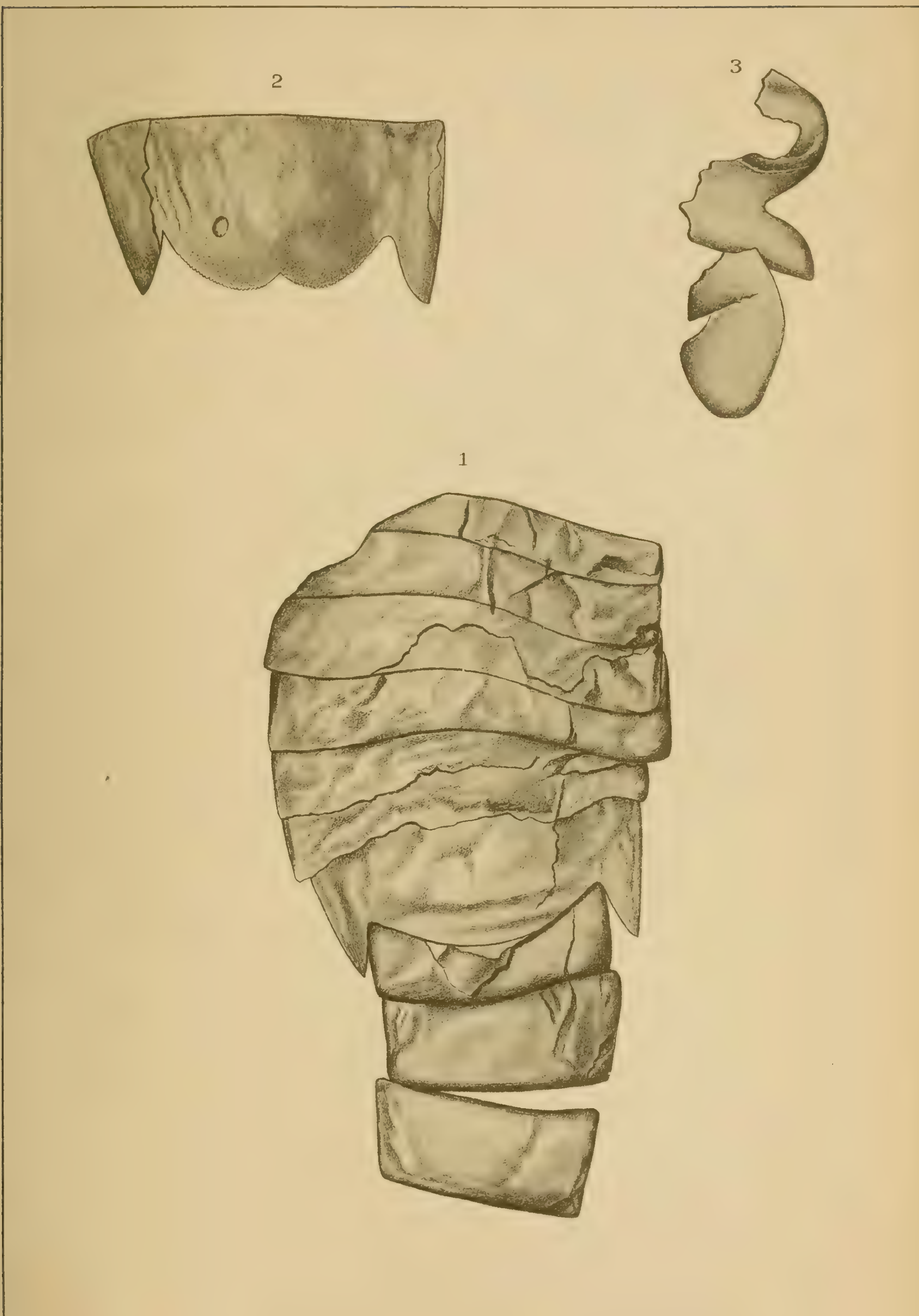

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PLATE 22

Eurypterus pittsfordensis *sp. nov.*

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1 Fragmentary ventral side of abdomen of male showing five joints, including gnathobase, of swimming foot; the five sternites and four postabdominal segments with their fringed posterior emargination. Natural size. Impressions of Leperditiae cover the surface

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PLATE 23

Eurypterus pittsfordensis *sp. nov.*

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1 An endognathite referred doubtfully to this species

2 Seventh and eighth joints of swimming foot showing the formation of the slightly expanded blade, the subtriangular inner appendage of the seventh, the incised margin of the eighth joint (palette) and the minute claw inserted on the same. x2½

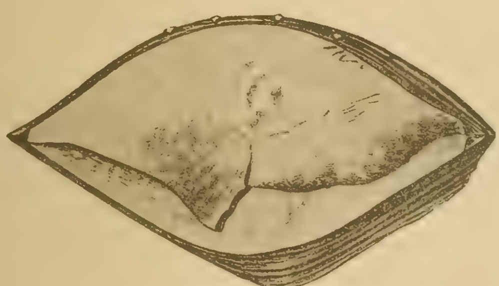
3 Cross section of postabdomen, showing the triangular scales on the tergite. Natural size

4 Section through postabdomen of a very large individual. Natural size

1

2

3



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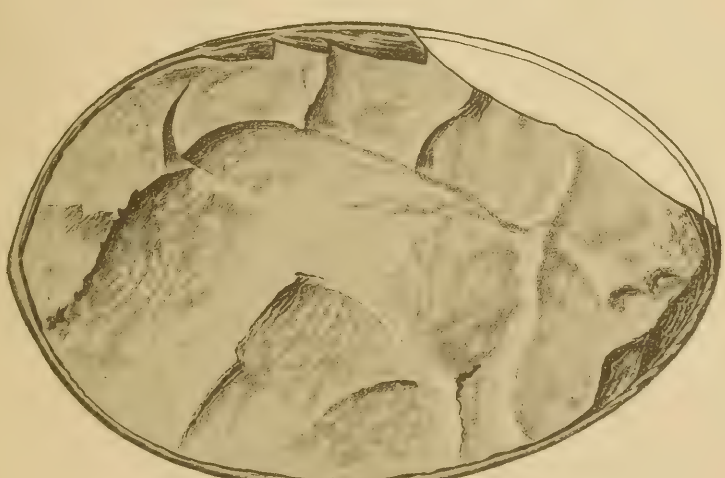

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PLATE 24

Hughmilleria socialis *sp. nov.*

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1 The free portion of the opercular appendage of a female showing the point of overlap and fusion of the two parts. x2

Eurypterus pittsfordensis *sp. nov.*

Page 1098

2 Fragment of sternite showing median cleft, transversal suture and lobe of anterolateral angles. Natural size

3 Metastoma showing notch and minute dentation of anterior end. Natural size

4 Coxal joint of fourth endognathite. x2½

5 Female opercular appendage. Natural size

Pterygotus *sp.*

Page 1104

6 Fragment of free ramus of chela. x4

Pterygotus monroensis *sp. nov.*

Page 1102

7 Cephalothorax. Natural size

Pterygotus *sp.*

Page 1104

8 Metastoma. Natural size

Pterygotus monroensis *sp. nov.*

Page 1102

9 Part of proximal joint of preoral appendage. Natural size

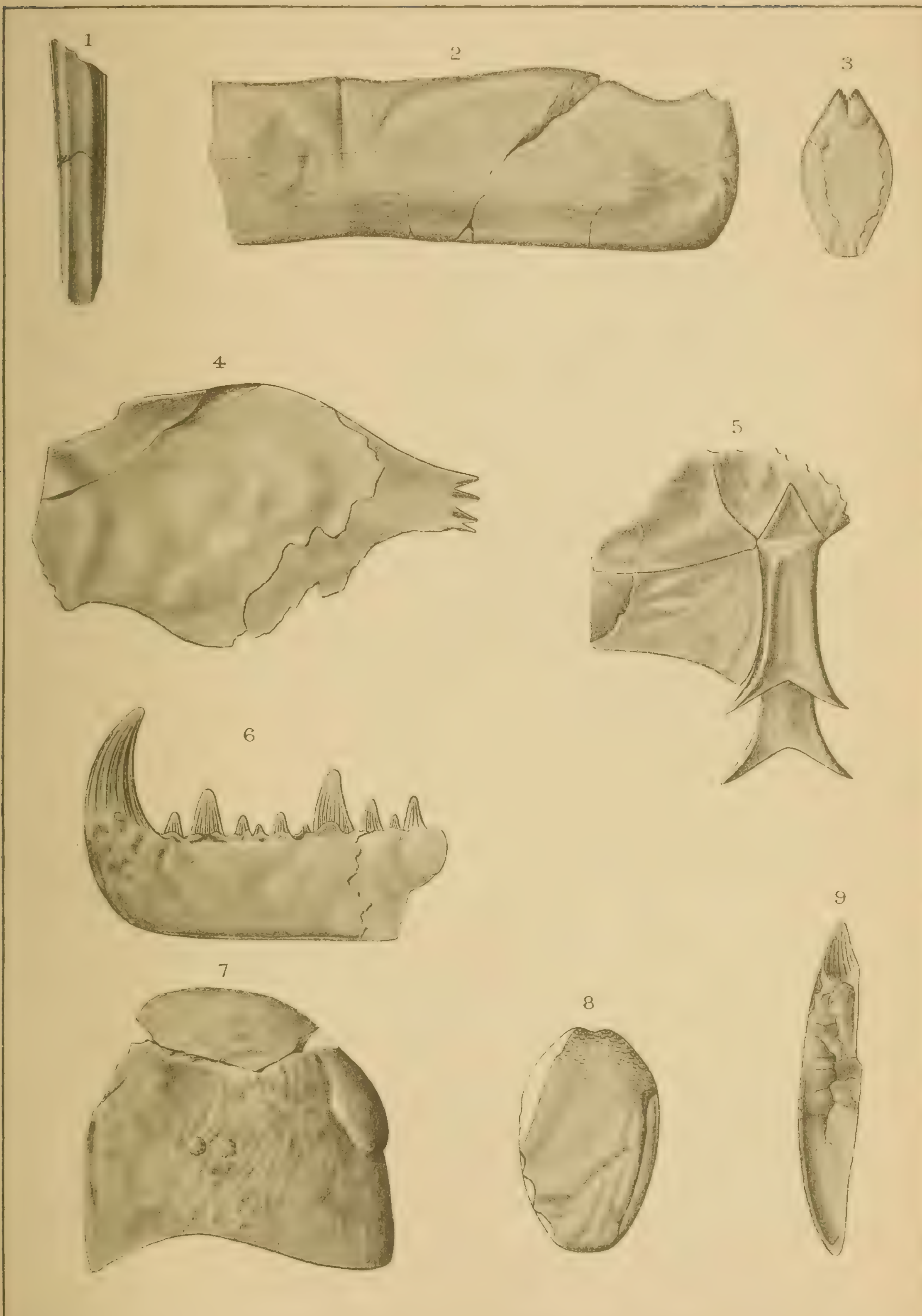

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PLATE 25

Hughmilleria socialis *sp. nov.*

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1 Male operculate appendage. Natural size

3 Ventral view, showing metastoma and one gnathobase in position. Natural size

4 Swimming foot, disjointed, showing the form of the joints. x2½

Eurypterus pittsfordensis *sp. nov.*

Page 1098

2 Male operculate appendage. Operculum shows median cleft and transversal suture. Natural size

5 Female second sternite, showing genital appendages. Natural size

6 Large sternite, showing transversal suture. Natural size

Rep. Paleontologist 1902. Plate 25

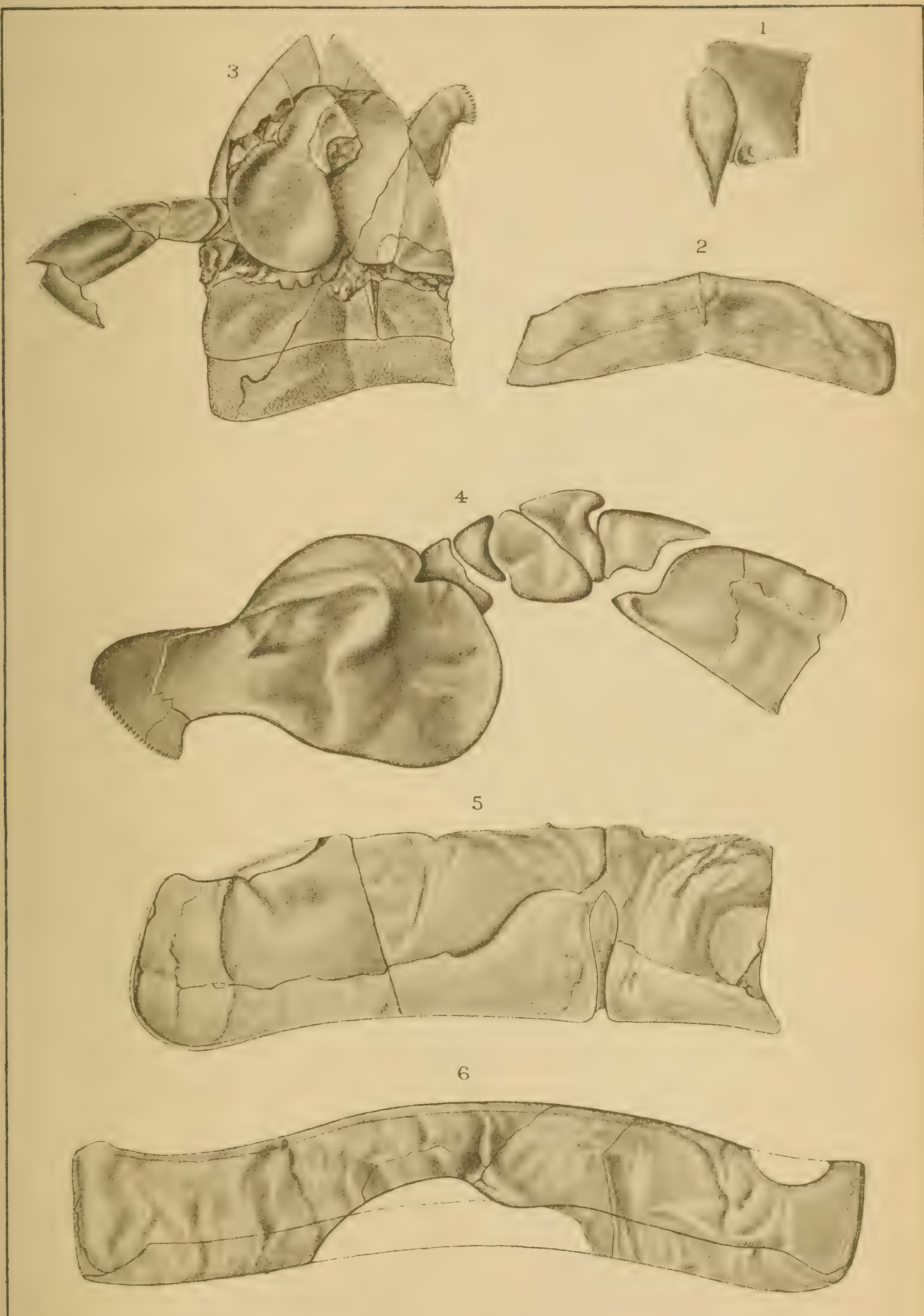

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PLATE 26

Unknown Eurypterid

Page 1105

1 Imperfect arm. Natural size

2 Group of arms and one body segment. Natural size

4 Imperfect arm. Natural size

Hughmilleria socialis *sp. nov.*

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3 Female appendage of second sternite. Natural size

5 Coxal joint of fourth endognathite, showing large perforation of the upper side. x2

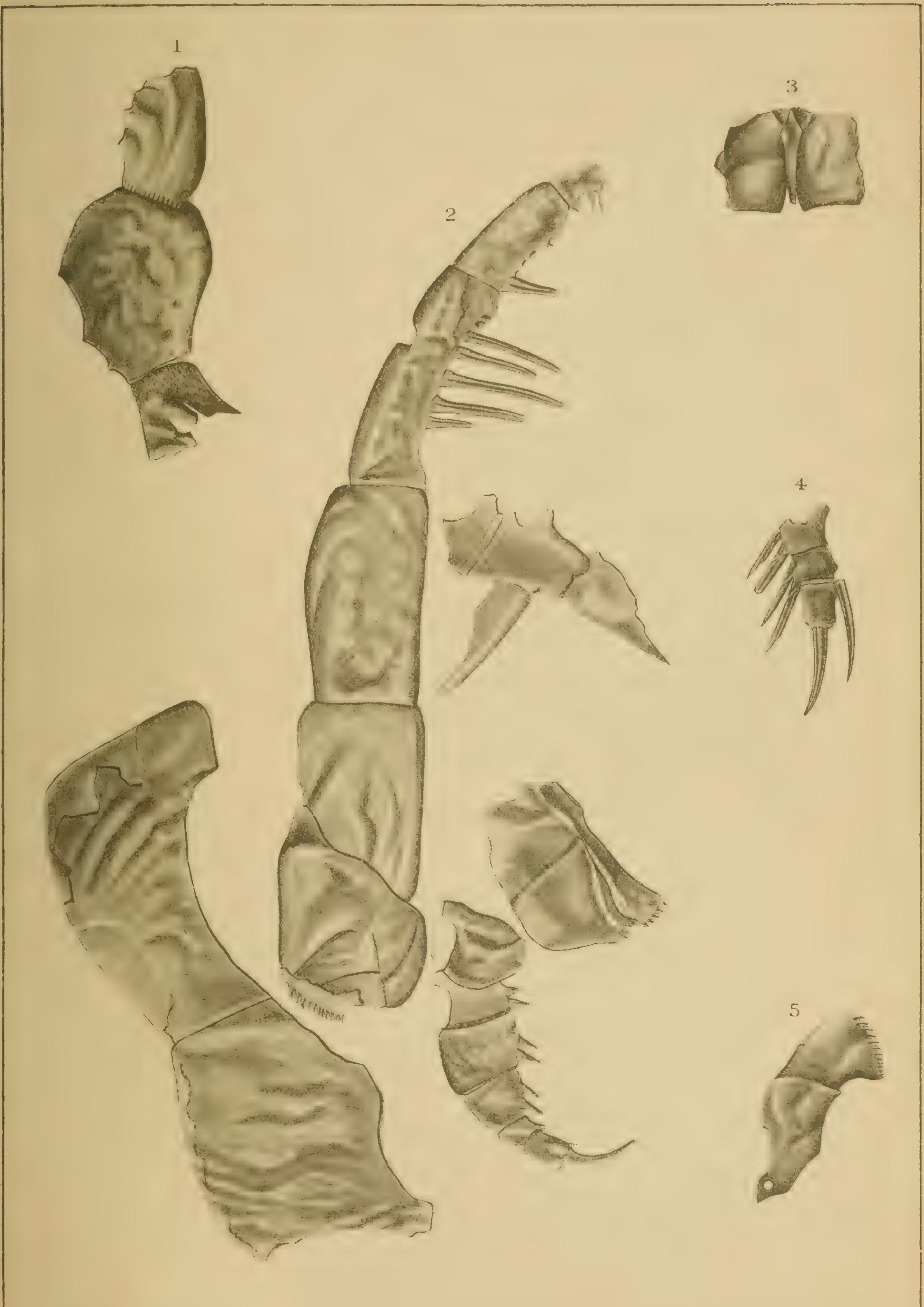

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PLATE 27

Protonympha salicifolia ***nov.***

Page 1237

1-4 Four views showing the obverse and reverse of two specimens. All natural size and all from the sandstones with Paropsonema, lying above the horizon of the Intumescens zone (Portage formation). Figures 1 and 2 are from Italy hill, Yates county, 3 miles northeast of Naples; figures 3 and 4 from the Tannery gully, Naples

DEVONIC WORMS

Rep Paleontologist 1902. Plate 27

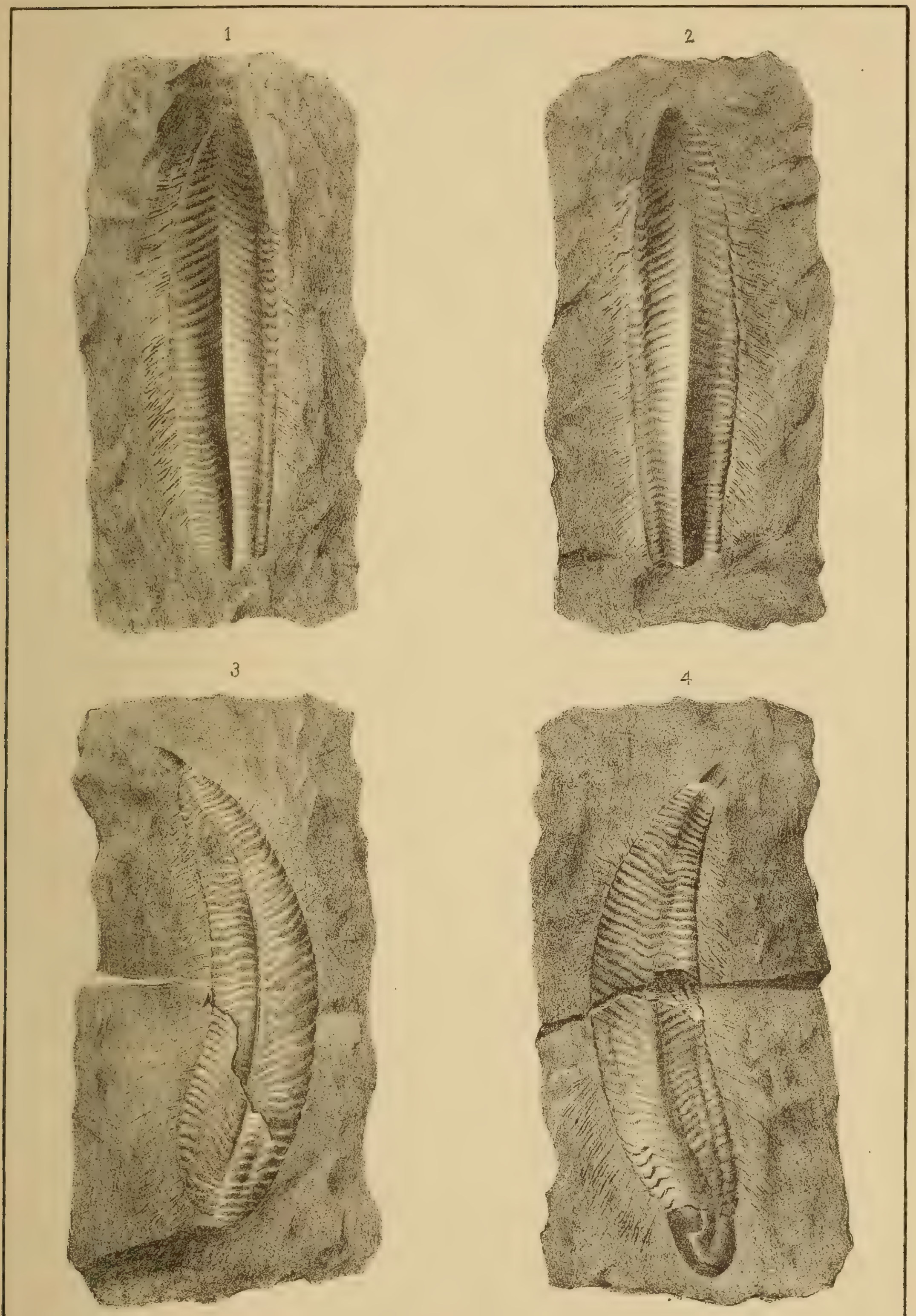

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PLATE 28

Protonympha salicifolia *nov.*

[*See* Pl. 27]

Page 1237

1 Drawn from a plaster cast of the natural surface

Palaeochaeta devonica *nov.*

Page 1238

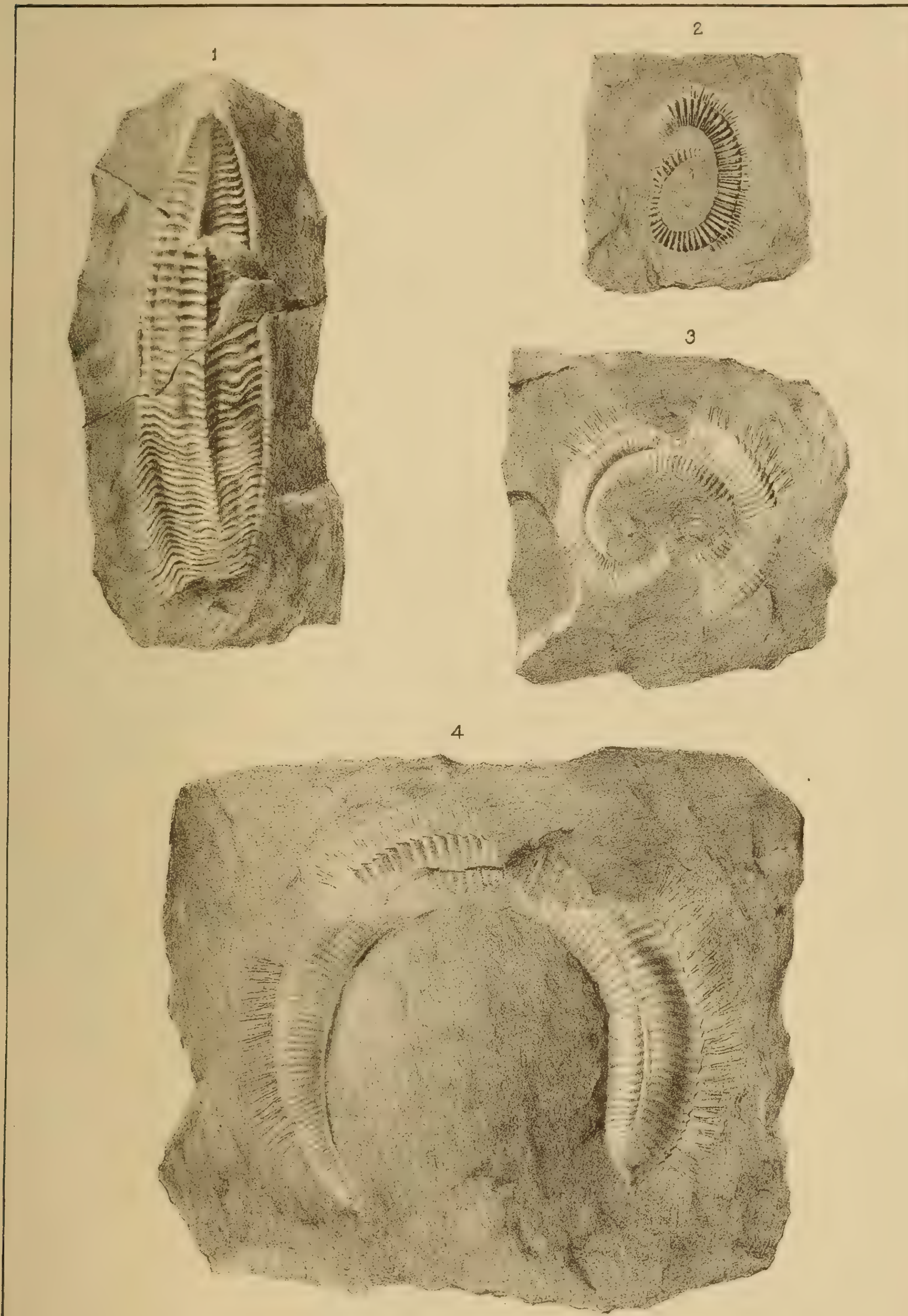
2 A small coiled specimen. x2. From the soft shales in Grimes gully, Naples

3 A larger but imperfect worm from the Tannery gully, Naples. x1.5

4 A still larger specimen from the same locality. x1.5

DEVONIC WORMS

Rep Paleontologist 1902. Plate 28



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University of the State of New York

New York State Museum

PUBLICATIONS

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Museum annual reports 1847–date. *All in print to 1892, 50c a volume, 75c in cloth; 1892–date, 75c, cloth.*

These reports are made up of the reports of the director, geologist, paleontologist, botanist and entomologist, and museum bulletins and memoirs, issued as advance sections of the reports.

Geologist's annual reports 1881–date. Rep'ts 1, 3–13, 17–date, O; 2, 14–16, Q.

The annual reports of the early natural history survey, 1837–41 are out of print.

Reports 1–4, 1881–84 were published only in separate form. Of the fifth report four pages were reprinted in the 39th museum report, and a supplement to the 6th report was included in the 40th museum report. The 7th and subsequent reports are included in the 41st and following museum reports, except that certain lithographic plates in the 11th report (1891) and 13th (1893) are omitted from the 45th and 47th museum reports.

Separate volumes of the following only are available.

Report	*Price*	*Report*	*Price*	*Report*	*Price*
12 (1892)	$.50	16	$1	19	$.40
14	.75	17	.75	20	.50
15, 2v.	2	18	.75	21	.40

In 1898 the paleontologic work of the State was made distinct from the geologic and will hereafter be reported separately.

Paleontologist's annual reports 1899–date.

See fourth note under Geologist's annual reports.

Bound also with museum reports of which they form a part. Reports for 1899 and 1900 may be had for 20c each. Since 1901 these reports have been issued as bulletins.

Entomologist's annual reports on the injurious and other insects of the State of New York 1882–date.

Reports 3–17 bound also with museum reports 40-46, 48-55 of which they form a part. Since 1898 these reports have been issued as bulletins. Reports 3-4 are out of print, other reports with prices are:

Report	*Price*	*Report*	*Price*	*Report*	*Price*
1	$.50	8	$.25	13	$.10
2	.30	9	.25	14 (Ent. bul. 5)	.20
5	.25	10	.35	15 (" 9)	.15
6	.15	11	.25	16 (" 10)	.25
	.20	12	.25	17 (" 14)	.30
				18 (" 17)	.20

Reports 2, 8-12 may also be obtained bound separately in cloth at 25c in addition to the price given above.

Botanist's annual reports 1867–date.

Bound also with museum reports 21-date of which they form a part; the first botanist's report appeared in the 21st museum report and is numbered 21. Reports 21-24, 29, 31-41 were not published separately.

Separate reports 25-28, 30, 42-50 and 52 (Botany bulletin 3), are out of print. Report 51 may be had for 40c; 53 for 20c; 54 for 50c; 55 (Botany bulletin 5) for 40c; 56 (Botany bulletin 6) for 50c. Since 1901 these reports have been issued as bulletins.

Descriptions and illustrations of edible, poisonous and unwholesome fungi of New York have been published in volumes 1 and 3 of the 48th museum report and in volume 1 of the 49th, 51st, 52d, 54th and 55th reports. The descriptions and illustrations of edible and unwholesome species contained in the 49th, 51st and 52d reports have been revised and rearranged, and, combined with others more recently prepared, constitute Museum memoir 4.

Museum bulletins 1887–date. O. *To advance subscribers, $2 a year or 50c a year for those of any one division:* (1) *geology, economic geology, mineralogy, general zoology, archeology and miscellaneous,* (2) *paleontology,* (3) *botany,* (4) *entomology.*

Bulletins are also found with the annual reports of the museum as follows:

Bulletin	*Report*	*Bulletin*	*Report*	*Bulletin*	*Report*
12–15	48, v. 1	20–25	52, v. 1	35–36	54, v. 2
16–17	50 "	26–31	53 "	37–44	" v. 3
18–19	51 "	32–34	54 "	45–48	" v. 4
				49–54	55, v. 1

The figures in parenthesis indicate the bulletin's number as a New York State Museum bulletin.

Geology. **G1 (14)** Kemp, J. F. Geology of Moriah and Westport Townships, Essex Co. N. Y., with notes on the iron mines. 38p. 7pl. 2 maps, Sep. 1895. *10c.*

G2 (19) Merrill, F: J. H. Guide to the Study of the Geological Collections of the New York State Museum. 162p. 119pl. map. Nov. 1898. [*50c*] *New edition in preparation.*

G3 (21) Kemp, J. F. Geology of the Lake Placid Region. 24p. 1pl. map. Sep. 1898. *5c.*

G4 (48) Woodworth, J. B. Pleistocene Geology of Nassau County and Borough of Queens. 58p. il. 9pl. map. Dec. 1901. *25c.*

G5 (56) Merrill, F: J. H. Description of the State Geologic Map of 1901. 42p. 2 maps, tab. Oct. 1902. *10c.*

G6 Cushing, H. P. Geology of the Vicinity of Little Falls, Herkimer Co. *In preparation.*

—— Crystalline Rocks of the Northeastern Adirondacks. *In preparation.*

Kemp, J. F. Crystalline Rocks of Warren and Washington Counties. *In preparation.*

Woodworth, J. B. Glacial Geology of New York. *In preparation.*

Economic geology. **Eg1 (3)** Smock, J: C. Building Stone in the State of New York. 152p. Mar. 1888. *Out of print.*

Eg2 (7) —— First Report on the Iron Mines and Iron Ore Districts in New York. 6+70p. map. June 1889. *Out of print.*

Eg3 (10) —— Building Stone in New York. 210p. map, tab. Sep. 1890. *40c.*

Eg4 (11) Merrill, F: J. H. Salt and Gypsum Industries in New York. 92p. 12pl. 2 maps, 11 tab. Ap. 1893. *40c.*

Eg5 (12) Ries, Heinrich. Clay Industries of New York. 174p. 2pl. map. Mar. 1895. *30c.*

Eg6 (15) Merrill, F: J. H. Mineral Resources of New York. 224p. 2 maps. Sep. 1895. *50c.*

Eg7 (17) —— Road Materials and Road Building in New York. 52p. 14pl. 2 maps 34x45, 68x92 cm. Oct. 1897. *15c.*

Maps separate 10c each, 2 for 15c.

Eg8 (30) Orton, Edward. Petroleum and Natural Gas in New York. 136p. il. 3 maps. Nov. 1899. *15c.*

Eg9 (35) Ries, Heinrich. Clays of New York; their Properties and Uses. 456p. 140pl. map. June 1900. *$1, cloth.*

Eg10 (44) —— Lime and Cement Industries of New York; Eckel, E. C. Chapters on the Cement Industry. 332p. 101pl. 2 maps. Dec. 1901. *85c, cloth.*

Eg11 (61) Dickinson, H. T. Quarries of Bluestone and other Sandstones in New York. 108p. 18pl. 2 maps. Mar. 1903. *35c.*

Mineralogy. **M1 (4)** Nason, F. L. Some New York Minerals and their Localities. 20p. 1pl. Aug. 1888. [*10c*]

M2 (58) Whitlock, H. P. Guide to the Mineralogic Collections of the New York State Museum. 150p. il. 39pl. 11 models. Sep. 1902. *40c.*

M3 (70) —— New York Mineral Localities. 110p. Sep. 1903. *20c.*

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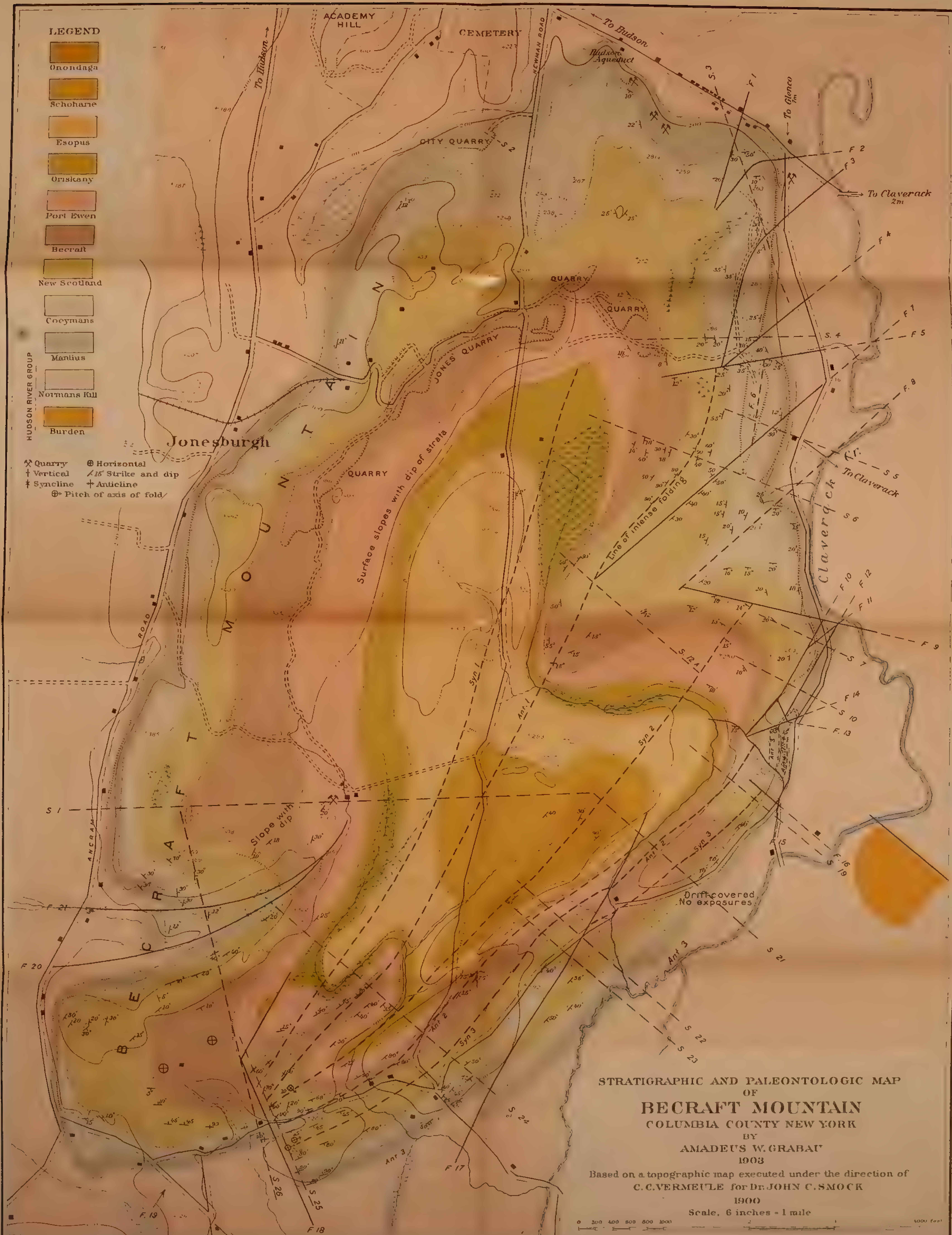
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Quarry
Horizontal
Vertical
15° Strike and dip
Syncline
Anticline
Pitch of axis of fold
ACADEMY HILL
CEMETERY
NEWMAN ROAD
To Hudson
Hudson Aqueduct
To Glenco 1m
To Claverack 2m
CITY QUARRY
QUARRY
JONES QUARRY
Jonesburgh
Surface slopes with dip of strata
Line of intense folding
To Claverack
Claverack Cr.
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Stratigraphic and paleontologic map of Becraft mountain

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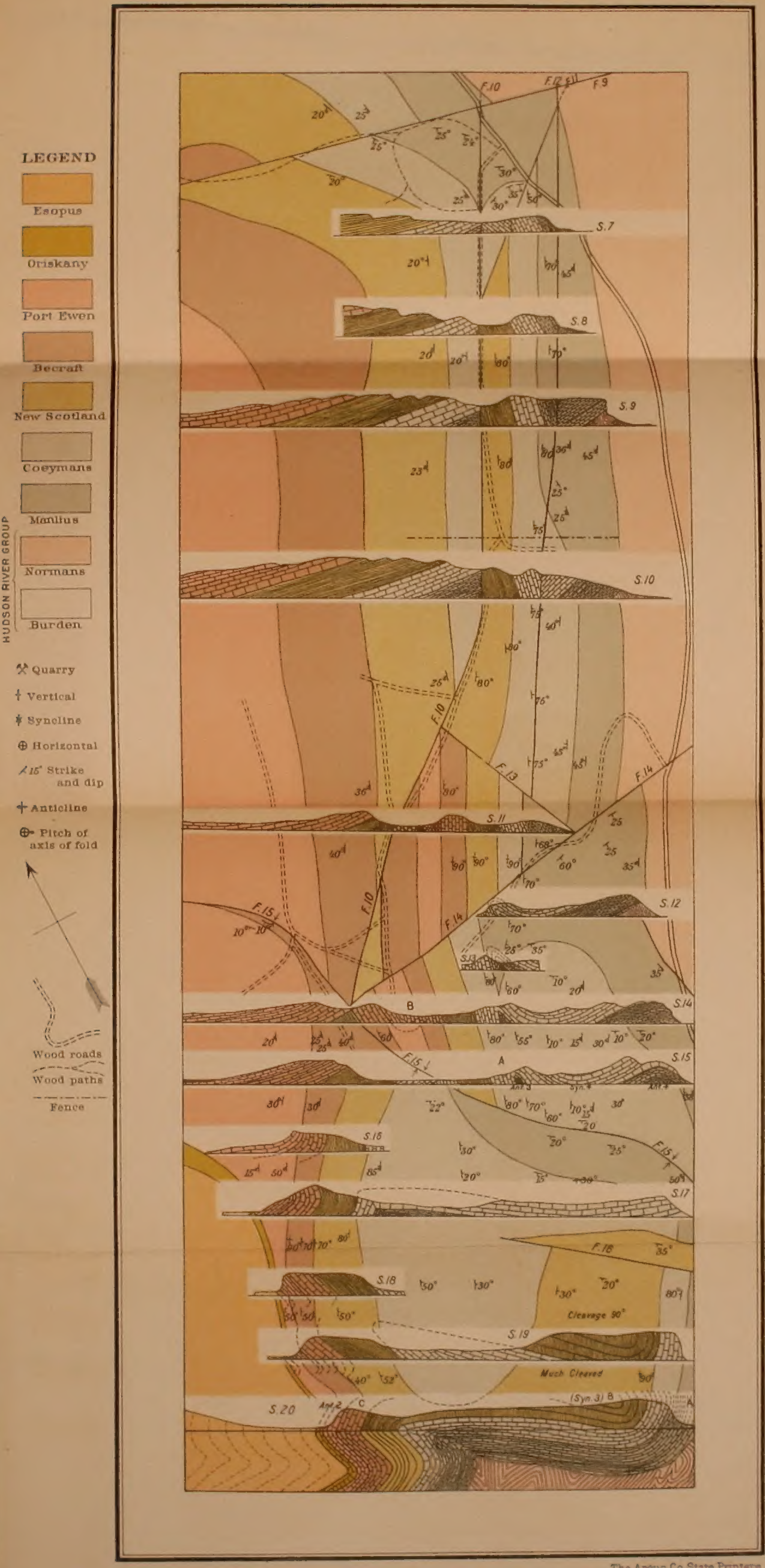

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